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AGRICULTURAL LAND DEGRADATION IN WESTERN CANADA: A PHYSICAL AND ECONOMIC OVERVIEW

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The list of reports on this subject are as follows:

1. Agricultural Land Degradation in Western Canada: A Physical and Economic Overview

2. Prairie Agricultural Development Directions

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4. United States Department of Agriculture Soil Conservation Activities on the U.S. Great Plains: Lessons for Agriculture Canada on the Canadian Prairies

5. Impacts and Program Delivery Aspects of Current Activities to Prevent Soil Degradation and Conserve and Improve Soil and Water Resources for Agriculture - Key Findings and Overview of Programs

6. An Overview of the Technology Transfer Systems for Soil and Water Conservation Practices in Western Canada and The United States

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AGRICULTURAL LAND DEGRADATION IN WESTERN CANADA
A PHYSICAL AND ECONOMIC OVERVIEW

EXECUTIVE SUMMARY

Commissioned by the Regional Development Branch of Agriculture Canada, the objective of this project was to provide resource information for the development of soil conservation policies in Western Canada. The project consisted of the following functions:

- Estimate the geographic location and extent of soil degradation.
- Estimate the severity of problems and identify trends.
- Conduct an economic assessment of the impact on crop yields and related costs of production.
- Identify potential ameliorative practices and opportunities.

The report examines the parameters of the following four land degradation issues:

- Soil salinization
- Soil erosion by wind and water
- Soil acidification, and
- Organic matter loss and associated nutrient decreases

for the improved land areas in the grain growing regions of Manitoba, Saskatchewan, Alberta and the Peace River area of British Columbia.

Land degradation has been identified as a serious issue in Western agriculture by Agriculture Canada and by a consensus of several public forums. The long term economic, social and environmental costs to establish and maintain a sustainable agricultural production system are very high, and require changes in the present agricultural industry.

The evaluation of the risk of future degradation requires a solid data and information base and a full understanding of soil, geological and climatic conditions; interrelationships of agricultural management practices and physical processes; as well as an ability to project interactions over time.

For example, although it may not "pay" farmers to arrest any one degradation problem, the simultaneous amelioration of two or three potential problems with an appropriate input "package" may very well have a very high payoff, both for the farmer and society in general. Adequate research required to identify input factors has generally been lacking for Western Canada in agriculture. Little has been achieved to date in documenting the effects of degradation or amelioration on yields because most research has concentrated on plot-scale experiments and development of research methods rather than on documentation of regional problems. Despite the unavailability of adequate regional inventory data and sufficient information, an attempt has been made in this research report to quantify the seriousness of the various degradation issues.

Soil Salinization

Secondary saline soils are man-induced and caused by agricultural practices or by changing surface water run-off. Secondary salinity is a result of addition, redistribution or concentration of soluble salt by ground water or surface water with summerfallow as the major contributing factor.

The lack of adequate inventory information on salt-affected soil limits the extent of risk evaluation. A geographic map of secondary salinity has been developed classifying three salinity risks (low, medium, high), four pH levels, and trend (static or increasing). The often-quoted rate of increase in saline areas of 10% per year appears to be too high for use in long term projections. The rate naturally varies from area to area and year to year. Areas of low, moderate and high salinity risk have been identified and indicate that man-induced salinity might be expected to increase by about one percent per year, given our prevailing technologies and trends.

The total area of improved land affected by secondary salinity is thus projected to increase from approximately 2.6 million acres in 1984 to 3.2

million acres in 2008. Saskatchewan has the largest acreage, but Alberta and Manitoba have the most intensive problems when evaluated at a Census Division level.

The estimated effects of salinity on yields have been based on a moderate level of salinity; at an electrical conductivity level of 6mS/cm, the yield reduction was 21% for wheat, 14% for barley and 24% for canola.

Estimated annual crop losses from salinity on the Prairies are projected to increase from about $104 million in 1984 to about $110 million in 1990, and about $128 million in 2008. This represents 1.5% of the total value of Prairie crop production, but in terms of lost net farm income, it is about five percent. The projected annual increase is about $0.5 million per year, indicative of what should be spent annually to arrest further man-induced secondary soil salinization. Of even greater importance are the cumulative costs over the next 25 years which, without amelioration and at a 10% discount rate, probably will exceed $1 billion, and about $1.6 billion including indirect costs.

Various methods of saline control and reclamation have been suggested such as the use of deep-rooted perennial crops, more intensive cropping with a gradual elimination of summerfallow, surface and sub-surface drainage, utilization of effective snow management practices, and the planting of salt tolerant crops.

Benefit-cost analyses have been reviewed with the following results: the best benefit-cost ratio is currently a rather marginal 1.11, and the worst, with given current grain prices and a discount rate of 10% about 0.6. Thus, it is concluded that it is unlikely that farmers can presently afford widespread adoption of salinity reclamation procedures. A radical change is required in cropping patterns.

The following three policy priorities are suggested:

- Document the problem, develop models, evaluate the effects and several other relevant actions.

- Determine the environmental impact, develop improved management practices, evaluate sources of amendments, determine crop tolerance, undertake plant breeding.
- Determine the impact of salinity on structures, roads and human health.

Public incentives appear to be essential at the present time to arrest increasing salinity. The farmer's time frame is too short and his short-term financial needs too great to adopt the practices required to sustain the long term productivity of the land.

Soil Erosion

Historic and ongoing soil erosion is the most serious single resource degradation issue facing Prairie agriculture today.

Erosion by water is generally considered to be the issue of greatest concern with wind erosion also of major concern. Many lands throughout the Prairies have experienced a 30-50% loss of topsoil with the result that their productivity cannot be replaced completely and, with fertilizers and other ameliorative practices, perhaps only to 75%.

The extent and severity of soil erosion have not been adequately documented, representing a serious information gap. A quantitative assessment of historic monitoring of current, and estimates of future soil losses on a regional basis are urgently needed since soil erosion rates vary with climatic, topographic and soil surface features. Using the limited data available and extrapolating the erosion risks, extent and severity of historic erosion have been plotted on a geographic soil erosion map.

In 1984, some 94 million acres were subjected to the risk of erosion in Western Canada, of which 12.4 million were in the low risk class, 48.6 million in the medium, and 33.1 million in the high risk category.

Alberta has the largest proportion of lands with high risk of wind and water erosion. Saskatchewan has the highest total area of erosion, totalling some 49 million acres of which 33 are in the medium risk class. In Manitoba, wind and water erosion of the soil is of great concern with management practices representing the prime causes; the continuing shift to corn, potatoes, and beans, in areas of high risk will result in increasing soil losses.

The effects of water and wind erosion had to be estimated as data for Western Canada are almost non-existent. A 100% loss of topsoil reduces the relative productivity, depending on crops grown on specific soils, from 100-80% for Solonetzic and Gray and Dark Gray Luvisols, and from 30-50% for Brown and Dark Brown soils.

The estimated and computed losses are staggering: the computed losses in 1984 for all three areas were about $468 million and are projected to increase to about $490 million in 1990 and to $558 million in 2008. The annual costs per improved acre in current dollars for the B.C. Peace River area were $6.55 in 1984, increasing to an estimated $6.87 in 1990 and $7.85 in 2008. For Saskatchewan, they were slightly lower and again lower for Manitoba. This translates to costs of up to $7,000 per year per farm in the most severe areas. The annual costs of erosion are presently in excess of seven percent of the total value of crop production in Alberta and almost five percent in Saskatchewan.

The direct cost to Western agriculture, projected over 25 years and discounted at 10%, has been computed at $4.5 billion. The annual incremental cost of soil erosion on the Prairies is approximately $3.75 million.

The principal thrust of soil conservation efforts should focus on reduced tillage and longer rotations with less summerfallow and more forages. Zero or minimum tillage refers to seeding and cropping untilled stubble creating the minimum amount of soil disturbance. But the economics from composite research findings indicates that zero tillage may result in lower yields, at least in the initial four to five years, and higher out-of-pocket farm operating costs.

Public policies are required which take into account the extent of private and public resource requirements. Once again, in the private farm sector the "bottom line" is profits. Many recommended erosion control practices result in marginal or reduced profits. There is no short-term payoff. Required cultural practices which would sustain the productivity of the soil would possibly not be of economic benefit to an individual farmer unless his planning horizon would extend to 50 years or more.

In the public sector, perhaps the most dangerous aspect is that the relatively slow effect on social well-being is almost insidious. Annual reductions in productivity are usually small and thus the effects of erosion often go undetected; the erosion of crop yields can even temporarily be masked with increased use of fertilizer. Thus, soil and water erosion is not perceived as being a high priority problem because the consequences of benign neglect would not immediately lead to any catastrophic or social consequences. It is future generations who will have to pay for this neglect.

A comparison of U.S. and Canadian expenditures on soil and water conservation in 1979 shows that federal expenditures per hectare were $41 for the entire U.S., $30 for Montana, $15 for North Dakota and $0.3 for the Canadian Prairies. State and provincial expenditures per hectare were $1.8 for Montana, $0.8 for North Dakota, $0.5 for Alberta, $0.4 for Manitoba and $0.2 for Saskatchewan.

Summarizing the needs, it is evident that substantially more basic research is urgently required on the location and extent of historic and current soil losses, economic importance, risk and rate of change as well as the private and public payoff of the various conservation methods. Increased awareness by extension services and the public is also required.

Soil Acidification

Most of the acid soils farmed on the Prairies were acid before farming due to the natural soil processes of leaching and microbial action. Acidity, however, can be increased with the addition of nitrogen and sulphur fertilizers.

Acid soils have been recognized for several years in the Peace River region and the Scott area of Saskatchewan, but a much wider distribution has been identified during the past 10 years. Acid soil maps have recently been prepared primarily in response to the concern about acid rain.

The current extent of soils with a topsoil pH of less than 6 has been estimated including a projection of the acidification occurring in the next 25 years. The extent of acid soils can be estimated with reasonable confidence but the extent of man-induced acidification is not known. There are some six million acres of acid soil in the grain growing region estimated to increase by 175,000 acres per year and reaching 10.6 million acres by the year 2008. The majority of these soils are in Alberta and the B.C. Peace River region followed by Saskatchewan and practically nil in Manitoba.

In the B.C.-Alberta Peace River region, an estimated 34% of the cultivated land, and 24% of the remaining cultivated land in Alberta, is in the near acid range and at risk of acidification. Acid soils in Alberta will increase from 4.2 to 6.8 million acres over the next 25 years. In Saskatchewan, the estimated extent of acid soils is projected to increase from 1.8 million acres in 1984 (or about 3.7% of the improved land base), to 3.6 million acres in 2008.

The relative productivity for wheat, barley and canola decreases by about 5-10% within a pH range of 5.6-6.0, and by about 15-25% within a pH range of 5.1-5.5.

The actual projected annual costs without ameliorative measures are $49.4 million in 1984 and projected to increase to $70.1 million in 1990, and $132.3

million in 2008. The annual costs for improved land are $1.14, $1.52 and $2.57 per acre for the same periods respectively.

The total projected direct costs without ameliorative measures over the next 25 years, discounted at 10%, are $683 million, and including indirect costs with GDP multiplier of 1.6, $1.092 billion.

The annual maximum expenditure suggested to arrest further acidification has been estimated at $3.5 million of which $2.1 million would be allocated to Alberta, 1.3 million to Saskatchewan and $0.05 to Manitoba.

Amelioration of acid soils is relatively straightforward by simply requiring a periodic application of lime to raise the pH. It should be done, depending on soil types, pH levels and crops, once every 10-15 years. Increased yields generally result in a payback of liming costs in less than two years.

The research requirements, though less critical than for other degradation causes, should nevertheless focus on the extent, location, cultural practices, and economic importance. Basic research would not be required except to improve the diagnostic and extension services. Emphasis should be directed towards adequate supplies of lime, and farm subsidies for product and transport costs. Existing programs should simply be upgraded.

Organic Matter Loss

Organic soil matter is lost by erosion and microbial action, and is diluted by cultivation. The rate of loss is highest in the initial years of cultivation with subsequent dramatic decreases. No evidence exists of a continuing general decline in the Dark Brown and Black Soil Zones. In general, organic matter levels are probably continuing to decline on most farms in the Brown Soil Zone primarily due to wheat-fallow rotation systems while remaining steady in the Dark Brown and Black Soil Zones.

Loss of organic matter results in loss of nutrients, loss of nutrient-supply power, and deterioration of physical properties of the soil. Low organic matter levels are responsible for surface crusting, higher bulk density, slower water penetration, lower available water capacity and higher erosion risk resulting in lower crop yields. The important goal in organic matter management is to recycle rather than to mine it.

The extent and severity of organic matter loss is strongly linked to management practices. Due to management variability at the individual farm level, no attempt was made to estimate the extent or severity by mapping and correlating yield reductions. An economic evaluation was undertaken to determine if the input costs only (which were not being translated into extra yields), could be used to indicate the severity of organic matter loss. Since this approach is sensitive to all soil degradation issues and not just organic matter loss, however, the costs cannot be isolated as being due to organic matter loss only.

Amelioration involves soil management practices replacing small organic matter losses with manuring, straw addition, fertilizing to increase growth, and continuous cropping or minimum tillage. These practices are being carried out by some farmers in all soil zones.

The effect on productivity due to organic matter loss is again very difficult to quantify because it is a factor of not just organic matter loss but also of other soil degradation effects. Therefore it is not presently possible to isolate the ongoing economic costs of organic matter losses.

Maintaining or improving organic matter levels on the Prairies is generally considered in conjunction with erosion control measures such as longer rotations, less summerfallow, more forages, and reduced tillage operations.

Considerable research has been conducted regarding the economics of reduced summerfallow and legume green manure cultivation to increase nitrogen levels.

Virtually all authors of nine identified studies undertaken in the last four years agree that summerfallow contributes to excessive organic matter loss, soil salinity, and wind and water erosion.

Benefit-cost ratios with respect to summerfallow reductions range from 1.09-1.25, reaching 1.6 for the Dark Brown, Black and Gray Soil Zones; although they were still below 1.0 in the Brown Soil Zone. It is concluded that to achieve the desired relatively large shift out of summerfallow operations, farm product prices would have to climb above current levels. Policy priorities should thus include an accurate determination by region of levels at which organic matter losses affect productivity and to what extent, and the development of an annual legume with high nitrogen fixing ability for green manuring.

The estimated trends of salinization, erosion and acidification in terms of annual incremental increase in acres affected and costs are summarized below.

	ACRES OF ANNUAL INCREMENTAL DEGRADATION		
by:	Salinization	Erosion	Acidification
Alberta + B.C. Peace	8,000	37,000	107,000
Saskatchewan	16,000	44,000	72,000
Manitoba	0	29,000	5,000
TOTAL	24,000	110,000	184,000
Annual Incremental Cost	$500,000	$3,750,000	$3,500,000

1.0 INTRODUCTION

The following working paper is intended to provide a summary review of the extent and severity of the major soil degradation issues on the prairies; and an estimate of the costs of lost production and the benefits of amelioration. This review was commissioned by Agriculture Canada, Regional Development Branch and is intended to be used as resource information for development of soil conservation policy in Western Canada. This report will form part of the input to Module 1: "To describe the status, seriousness, and growth trends of soil degradation, moisture conservation and land supply issues and problems related to agriculture in Canada's prairie physiographic region".

The land degradation issues addressed are:

a) salinization
b) erosion
c) acidification
d) organic matter loss

The report and the accompanying maps provide estimates of the risk, extent and severity of decreasing land quality and the associated economic costs. Benefits of selected amelioration opportunities are also described. The land base considered is the improved land (Statistics Canada, Census of Agriculture, 1981) in the grain growing region of Manitoba, Saskatchewan, Alberta and the Peace River area of British Columbia. Irrigated areas and areas used primarily for grazing (unimproved pasture) have not been included.

This report attempts a quantitative assessment of issues that are usually described qualitatively. As good regional inventory data are not available for most of these issues the estimates of extent and severity are based on limited information and several assumptions. Estimates of extent of degradation and associated costs were obtained by aggregating estimates at Census Division level to provincial and Prairie levels. This procedure provides a regionalization of the issues (areas with greatest effects can be identified on a Census

Division level), and minimizes the amount of error in the total estimates. Estimates of total costs due to salinity or erosion or acid soils are intended to identify the magnitude of the production loss currently and in 25 years, but the actual values should be considered to have fairly wide confidence intervals.

This report is not intended to be an exhaustive literature review of the issues, which would duplicate the efforts of PFRA (1983), and Coote et al., (1981); but rather an estimate of the extent, severity and economic importance of soil degradation issues, and ameliorative opportunities. This project was conducted on a budget for 80 professional person-days in a short calendar period, and is intended to be a quick review of the issues.

1.1 Background

1.1.1 Awareness

The issue of declining agricultural land quality has been identified as an international problem common to many areas of the world (Eckholm and Brown, 1977; Brown, 1979, 1978). This has led the United Nations Food and Agricultural Organization (FAO) to adopt a World Soil Charter (FAO, 1982); and the International Society of Soil Science to prepare a plan of action to implement a World Soils Policy (ISSS, 1982), both of which are aimed at soil conservation.

Land degradation issues in Western Canada have been the subject of several recent public hearings, workshops, and reviews including the Standing Committee on Agriculture, Fisheries and Forestry to the Senate of Canada (1984); the Environment Council of Alberta agricultural land base public hearings and information report series (1981-84); the Alberta Land Use Hearings (1976); the Western Provincial Conferences on Rationalization of Water and Soil Research and Management (1982 & 1983); and the Alberta Soil Science Workshop entitled Agricultural Land - Our Disappearing Heritage (1981).

The concensus of these public forums and reviews is that land degradation is a serious issue in Western Canada, and the long term sustainability of production in many areas will require changes in the present agricultural system. This reality is partly obscured by increasing production as a result of various inputs but the trend is to higher costs of production and "lack of a sustainable system". Long term costs will be very high (economically, socially and environmentally).

1.1.2 Extent and Severity of the Problem

Despite the recognition of the seriousness of land degradation very little documentation of the actual geographic extent and severity and rate of increase of the problems, and their economic impact has been achieved. This was identified as a serious information gap in 1961 by W.E. Johnson and has more recently been stressed by the Senate Standing Committee on Agriculture, Fisheries and Forestry (1984), Coote (1983), PFRA (1983) and Bentley (1981). As a result the extent and severity of problems in most areas is inadequately known. Most research on land degradation issues has concentrated on plot-scale experiments or development of research methods (both of which are necessary) rather than documentation of problems and contributing or ameliorating practices on farm or regional scales. Documentation of the magnitude, severity and current rate of degradation is very difficult but is necessary to determine private and social costs and to demonstrate a benefit to soil conservation (Crosson, 1984). Deciding (or justifying) how much should be spent to prevent soil degradation requires an estimate of the value of the lost productivity.

Several recent publications have summarized the issues and attempted to evaluate risk for future degradation (PFRA, 1983; Coote et al., 1981). Risk evaluation requires an understanding of soil, geological and climatic practices; an understanding of interrelationships of agricultural management practices and physical processes; and an ability to project or model changes and interactions over time. There are models and procedures for estimating

soil losses by water erosion for example, but the research required to identify the input factors for the model has not been done in Western Canada. Risk assessment and prediction are therefore very difficult to do with any confidence.

Very little has been achieved in documenting the effects of degradation, or of amelioration, on yields. Some farm-level research has been undertaken recently in Saskatchewan under the Farmlab program; and some in Alberta under the Farming For The Future farm demonstration program. Most research has, however, been limited to a few plot-level programs. Relationship of erosion losses, organic matter losses, salinization and acidification to yields are therefore limited to estimates based on very poor data. The same is true for estimating the benefits of amelioration or conservation programs.

1.1.3 Amelioration

Some agricultural lands have degraded to the point that original levels of productivity cannot be restored at reasonable cost. This is the case with severely eroded or salinized soils. Application of existing technologies would ensure maintenance, (and in some cases enhancement) of the productive potential of most of our farmed land, however, these technologies are not being employed by most farmers.

The reasons farmers do not adequately employ soil conservation technology were summarized by Bentley and Leskiw (1983) as being:

1. soil maintaining practices cost money and returns on such investments are uncertain,
2. adherance to old ideas; resistance to change,
3. recommendations have not been validated in real farm situations,
4. recommended practices are perceived as being impractical, and
5. recommended practices are too difficult to employ.

1.2 Objectives

The objectives of this review are generally:

1. to estimate the geographic location and extent of soil degradation problems,
2. to estimate the severity of problems and analyze trends,
3. to conduct an economic assessment of impacts on crop yields and related costs of production, and
4. to identify potential ameliorative practices and opportunities.

More specifically the soil degradation issues to be addressed are:

a) soil salinization,
b) soil erosion by wind and water,
c) soil acidification, and
d) organic matter loss and associated nutrient and tilth decreases.

In addition to the land degradation issues the availability of new agricultural land and the opportunity for expansion within the existing agricultural areas is summarized. Soil moisture conservation is recognized as a major need on the prairies, and is related to cropping practices which affect soil quality but will not be assessed as a separate issue. Degradation issues related to irrigated and pasture-based agriculture will not be considered.

1.3 Methodology

1.3.1 Overview of the Issues

A brief overview of each degradation issue was prepared to define terminology and concepts; explain causes and effects; and to identify remedial opportunities. This type of information is readily available from several sources, notably PFRA (1983) and Coote et al. (1981).

1.3.2 Estimation of Spatial Distribution, Extent and Severity

Map-based data depicting the extent of land degradation are not available for most of Western Canada.

Salinization

Maps of saline soils and risk of salinization are available for Saskatchewan and Manitoba, and preliminary maps of dryland salinity and seeps are available for part of Alberta; but compatible maps of secondary salinity (dryland salinity) of the entire region are not available. These had to be prepared for this project; using several data sources and many assumptions based on professional judgement.

Organic Matter Loss

Organic matter loss and associated problems represent a multitude of causes and processes, most of which are related to management practices. This does not lend itself to mapping, except in very general terms (by soil zone), therefore an economic approach was attempted to identify effects of organic matter loss (see Appendix C). This analysis was also sensitive to effects of erosion, acidification, salinity, and several other issues, and therefore could not identify the costs of only O.M. loss.

Acidification

Acidification of soils is a very poorly known topic in terms of how much man-aggravated acidity is present. We took the approach of mapping the total extent of acid soils - most of which were acid before they were farmed but have been further acidified in most cases. The estimated annual increase in acid soil extent and severity provides an estimate of the severity of acidification by agricultural inputs.

Erosion

Maps of the extent of severely or partially eroded lands are not available, except for a few areas where eroded land percentages were identified during soil surveys in Saskatchewan (since about 1960) and in Alberta (two counties). Risk maps for wind erosion and water erosion are available (Coote et al., 1981)

on a general scale. We have estimated extent and severity of erosion by extrapolating available information on a soil zone - landform - soil type basis to the grain growing region of western Canada (see Appendix A). This produced a (low confidence level) estimate which should be considered to be a first approximation of a very complex task.

Maps of salinized soils, eroded soils, and acid soils were overlayed on a base map with Census Division (C.D.) boundaries and the boundary of the grain producing area. Estimates of the amount of Improved Land (as used in Canada Census data) affected by each degradation issue in each C.D. were produced by pro-rating the degradation issue map units over the Improved Land area. Estimates of areas were then summarized by province and totalled for the grain growing region.

1.3.3 Estimates of Rates of Change and Predictions for 25 Years

Estimates of rates of change and future predictions for salinization, acidification, and erosion were based on evaluation of soil and climate factors and management practices and trends (refer to Appendix A). Assignment of Risk Classes and trends were based on established procedures, or opinions of various soil scientists in western Canada.

1.3.4 Estimates of Actual and Projected Productivity Losses

The effects of salinity, acidity and erosion on crop yields also had to be estimated, using limited data from a few research projects, and several assumptions to accommodate various crops in several climatic regions, on several soil types (refer to Appendix A). Yield reductions were estimated on a basis of "no compensating inputs being added" to avoid the masking problem that often occurs.

2.0 THE PRAIRIE LAND BASE

2.1 Overview

An excellent assessment of the land resources of the prairie provinces for grain production was prepared by Acton et al. (1980), and the subject has been reviewed by several other authors, notably Shields and Ferguson (1975), Simpson-Lewis et al. (1979) and Dumanski and Stewart (1981). In simple terms essentially all of the good quality land for grain production is presently in use. Marginally suitable new land is available for expansion of the land base, but continued agricultural productivity is dependent on the maintenance of the quality of our productive soils and not on expansion into new frontiers (Coote et al., 1981; Bentley, 1981; Thompson, 1981; Pettapiece and Lindsay, 1981; Geno and Geno, 1976; Shields and Ferguson, 1975). A summary of the current agricultural land base by province is presented in Table 2.1.

Table 2.1
THE PRAIRIE AGRICULTURAL LAND BASE, 1981
(Millions of Acres)

Province	Ag. Land Base	Cropped	Fallow	Improved Pasture	Total Improved	Total Unimproved
Alberta	47.218	20.859	5.450	3.908	30.951	16.267
Saskatchewan	64.117	29.012	16.567	2.410	48.639	15.477
Manitoba	18.819	10.923	1.479	.871	13.601	5.219

Source: Statistics Canada, Census of Agriculture, 1981, Ottawa, 1982.

2.2 New Agricultural Land

Large amounts of potentially arable lands have been identified in northwestern Alberta by several authors as being the major area for agricultural expansion in western Canada. Hu Harries and Associates (1974) estimated 10 to 18 million acres; Shields and Ferguson (1975) estimated 23.7 million acres; and Pettapiece and Lindsay (1981) estimated 18 million acres of land with some potential for arable agriculture. These estimates include land suitable for improved pasture - not for grain production. A more detailed evaluation by Marciak (1983) of land that is actually developable, and would not require very large public costs to develop new transportation trunks and service centres identifies only three million acres of potentially improvable land in northwestern Alberta. Most of this land is presently under forest management agreements which limits its availability, and the soils are acid and have low natural fertility.

Acton et al. (1980) estimated a land reserve of 31.5 million acres (1976 base) in the three prairie provinces, 18.6 million of which was suitable for wheat although very little was well suited.

Reduction of fallow was identified as a major source of expansion of cropped acres by the Canada Grains Council (1982). The Canada Grains Council projections of land use changes and productivity increases to the year 1990 are the best estimates available for future trends. The Canada Grains Council report estimates the potentially arable land base at 118 million acres (Table 2.2), 88.4 million of which was then devoted to crop production or improved pasture, leaving a reserve of 29.4 million acres. Most of the reserve land is only marginally suitable for grain production and much of it is not available for agriculture. The Canada Grain Council's estimate of three million acres of new land put into production by 1990 probably represents most of what will be added in 25 years. Most of this expansion will be in the Peace River area of Alberta, and will use most of the easily developable land in that region (Marciak, 1983).

Table 2.2
CANADA GRAIN COUNCIL (1982) PROJECTED CHANGES IN THE PRAIRIE LAND BASE TO THE YEAR 1990 (millions of acres)

Total Potentially Arable Land	118
Improved Land	88.4
Reserve	29.4
New Land in Production by 1990	3.0
Summerfallow Acreage (1981)	22.9
Summerfallow Acreage (1990)	17.7
New Cropland by Reduction of Fallow (1990)	5.2

Source: Canada Grains Council (1982) Prospects for the Prairie Grain Industry, 1990

Greater opportunity for increased production can be realized by increasing the cropland acreage by reduction of summerfallow acres. The Canada Grains Council estimated that 48.5 percent of the increase required to meet the 1990 wheat production projection would be realized by reduction in summerfallow; 30.2 percent would come from improved yields; and 21.3 percent from new lands. These estimates were based on a summerfallow acreage target of nearly 18 million acres in 1990, which could be further reduced by the year 2008. Predictions of rate of decrease in summerfallow acres are however, often wrong (Campbell and Biederbeck, 1980). Rennie et al. (1979) estimated the summerfallow acreage would be reduced to 15.1 million acres by 1990.

2.3 Amelioration of Solonetzic Soils

The improvement of Solonetzic soils by deep plowing or deep ripping and liming is currently of interest in east-central Alberta. Yields can be increased on soils presently in grain production, and some unimproved pastureland can be brought into grain production by deep plowing. Solonetzic soils in the Peace River area are not considered suitable for deep plowing (J. Hermans, Alta. Agric. pers. comm.). The total acreage of Solonetzic soils estimated by Alberta Agriculture (Land Use Branch, Alta. Land Base Study, Aug. 1984) to be suitable for deep plowing is 5.5 million acres. Only some (unknown) portion of these suitable soils will actually respond with yield increases (J. Hermans, pers. comm.) and response appears to be limited to years when moisture is at fairly high levels (Hermans and Palmer, 1982). Soils in the Black and Dark Brown Soil Zone respond best to deep plowing.

Once improved, Solonetzic soils may still require more intensive and often unique management practices to maximize production. These measures include: (1) improved drainage, (2) very careful seedbed preparation, (3) special fertilizer applications, (4) chemical amendments, (5) deep sub-soiling, and/or (6) deep plowing (Hermans and Palmer, 1982, pp. 301-315).

With respect to the economics of improving the productivity of Solonetzic soils, our concern here focuses on the feasibility of deep plowing, assuming farmers are able to obtain yield improvements (after 3-4 years) similar to those indicated in Table 2.3 following:

Table 2.3
COMPARISON OF YIELD RESPONSE FOR WHEAT (kg/ha)
ON DEEP PLOWING TEST PLOTS

Alberta Site	Year Deep Plowed	Crop Year	Check	Deep Plowed	Difference
Kneeland	1976	1979	1982.4	3306.2	+ 67%
		1980	1982.4	3131.5	+ 58%
		1981	645.1	1626.2	+ 152%
		1982	severe hail	damage	
Iles	1976	1981	1626.2	2977.0	+ 83%
		1982	2876.2	4415.0	+ 54%
Lyster	1976	1980	2647.7	4556.2	+ 72%
		1981	1155.8	2083.2	+ 80%
		1982	3178.6	3521.3	+ 11%

Source: Hermans and Palmer, 1982, p. 309

The most recent and comprehensive economic analysis available does, in fact, suggest that this should be economically feasible (Alberta Agriculture, August, 1984).

Table 2.4
BENEFIT-COST RATIOS REGARDING THE DEEP PLOWING OF SOLONETZIC SOILS (Discount rate = 5%)

Soil Zone	B/C Ratio
Black	4.37
Dark Brown	2.13
Brown	1.97

Given the product prices utilized in other Sections of this report and assuming that a discount rate of 10% per annum is appropriate, our own guesstimates would only be slightly less optimistic:

Black	3.23
Dark Brown	1.58
Brown	1.46

Nevertheless, adoption of these techniques by farmers has been slow due to the relatively high cost and large risks involved. In addition, the natural variablility in these soils makes it difficult to extrapolate information from one site to another. Thus at this point in time, research is strongly recommended to first develop the means of characterizing those solonetzic soil types that will respond best to the available management techniques (Hermans and Palmer, 1982, p. 313). Thereafter, more economic analysis is highly desirable.

2.4 Drainage of Wetlands for Agriculture

Drainage of wetlands is currently increasing, and regional and provincial schemes are being considered. The amount and quality of land that can be drained is the subject of a current inventory program in Alberta, but no estimates for any of the provinces are available at this time.

3.0 SOIL SALINIZATION

3.1 Overview

Saline soils in Western Canada are often classified in two groups: 1) the "primary" or geological saline soils which were saline before agriculture began and have never had any productive capability; and 2) the "secondary" or man-induced saline soils (also called dryland salinity) which developed due to agricultural practice or due to changing surface water runoff patterns that affect agricultural lands (approach consistent with Ballantyne, in press; Sommerfeldt and Paziuk, 1984; Vander Pluym et al., 1981). Secondary salinity may occur as a spread of salinity, or the development of saline soils in areas where the soils were previously not saline at the surface.

It is secondary salinity that is the product of the soil degradation process of salinization. This includes saline seeps and expansion of saline or alkali sloughs but does not include saline or alkali soils of pre-agricultural origin. This is also the dynamic part of saline soils that control and ameliorative practices are applied to. There is considerable lack of agreement between soil scientists in western Canada as to the extent, severity, risk of spreading, and rate of spread of salinity.

Secondary salinity is a result of addition, redistribution, or concentration of soluble salts by groundwater or surface water (Henry and Ballantyne, 1980; Sommerfeldt and MacKay, 1982; Greenlee, 1966). Summerfallowing has been identified as the major contributor to the saline seep type of secondary salinity (Sommerfeldt et al., 1978; Vander Pluym, 1981, 1978). The fallow-wheat cropping system uses less water than native prairie grass, and the amount of water that "leaks" downward can be sufficient to change a sensitive groundwater system resulting in new or larger discharge areas such as toe-slope or side-hill seeps. Discharge areas can also occur on fairly level land. While moving through the subsoil the salt content of the water is enriched, and these salts are deposited at the soil surface in the discharge area. The side-hill seep type of salinization occurs commonly in southern Alberta

(especially southwestern Alberta) (Christie, 1976; McCracken, 1973; Vander Pluym, 1981, 1978) and in southern Saskatchewan (Henry and Ballantyne, 1980; Rennie and Ellis, 1978). Toe-slope seeps appear to be aggravated by agriculture in Manitoba, but side-hill seeps are insignificant (B. Eilers, Canada - Manitoba Soil Survey, pers. comm.). The "evaporite ring" or "bathtub ring" type of saline area occur around the edges of saline sloughs throughout the Prairies. These can spread slightly due to an increase in the size of the slough as a result of changes to surface water runoff patterns or can decrease in size in response to slough drainage. A net change in area over Western Canada is very difficult to estimate, and is probably fairly insignificant.

3.2 Estimation of Risk, Extent and Severity

General scale inventories of secondary salinity have recently been compiled for Saskatchewan (Ballantyne, in press), and for part of southern Alberta (Alberta Environment, 1973). A more recent inventory of most of southern Alberta was released by Sommerfeldt and Paziuk (1984) as this report was being completed, but the data were not available for our estimates. A map of salt-affected soils (primary and secondary salinity) of Manitoba is also available (Eilers, file report). Each of these data sources required several interpretations to estimate risk, extent, and severity of secondary salinity on a consistent basis across the grain-growing region. Severity of salinization varies from low (with slight effects on crops) to severe (with total crop loss) over short distances, and few correlations of severity and spatial extent of salinity are available. We have, therefore, relied on several assumptions and data extrapolations which results in estimates with a low confidence level.

Several factors contribute to this low confidence, but primarily it is the lack of inventory information to document the problem that is limiting. Various estimates of "saline lands" have been made over the past 15 to 20 years which vary widely (Table 3.1) but these estimates were often not based on systematic inventories and it was often not clear if they referred to total saline land or

Table 3.1
ESTIMATES OF SECONDARY SALINITY IN WESTERN CANADA AS DOCUMENTED IN THE LITERATURE COMPARED TO PRESENT ESTIMATES

Alberta	
McCracken (1973b)	- Warner County 3.2% dryland salinity - Vulcan County 3.6% dryland salinity - Willow Creek 8.1% dryland salinity - Peigan I.R. 2.4% dryland salinity
Alta. Agriculture (1979)	- 0.25 M ac. of dryland (secondary) salinity in Alberta
Vander Pluym (1982) as cited by Lilley, 1982	- 0.5 M ac. of Alberta farmland are severely affected by salinity
PFRA (1983) referencing Vander Pluym et al. 1981	- 0.5 M ac. of dryland salinity
Sommerfeldt & Paziuk (pers. comm. 1984)	- 1.5 M ac. secondary salinity in southern Alberta including pasture land and irrigation districts, equal to 10.7% of total land area - 7.1% secondary salinity - 3.6% primary salinity
This Report	- 0.935 M ac. secondary salinity in improved land area - equal to 3% of land base considered - most severely affected C.D.'s have from 6 - 9% of improved land salinized
Saskatchewan	
Rennie & Ellis (1978) interpreting Crosson 1976 (map)	- 4.0 M ac. of improved or cultivated land was affected by salinity
Campbell & Biederbeck (1980) interpreting Crosson 1976 (map)	- 4.1 M ac. are affected by dryland salinity
Holm (1982c)	- 4.94 M ac. affected by salinity
PFRA (1983) referencing Vander Pluym et al. 1981	- 4.0 M ac. of dryland salinity
Rennie (pers. comm. 1984)	- 3.0 M ac. dryland salinity
This Report (using Ballantyne, in press)	- 1.54 M ac. secondary salinity on improved land - equal to 3% of land base considered - most severely affected C.D.'s have from 3-4% of improved land salinized

Table 3.1 cont'd
ESTIMATES OF SECONDARY SALINITY IN WESTERN CANADA AS DOCUMENTED IN THE LITERATURE COMPARED TO PRESENT ESTIMATES

Manitoba	
Patterson & McAndrews (1982) interpreting Eilers 1978 (map)	- 0.9 M ac. dryland salinity
PFRA (1983) referencing Vander Pluym et al. 1981	- 0.9 M ac. dryland salinity
This Report (using Eilers 1978 map)	- 0.9 M ac. of land with saline inclusions - 0.086 M ac. secondary salinity on improved land - equal to 0.6% of land base considered - most severely affected C.D.'s have from 2-4% of improved land salinized

to secondary salinity of improved lands - which led to several misinterpretations. We have used the most recent and we feel the most accurate inventory data available to estimate the amount of improved land affected by secondary salinity. We feel these estimates are realistic and compare reasonably well to other good estimates.

We have prepared a map of secondary salinity risk and extent (rear pocket) for the grain growing region of western Canada (excluding irrigated lands) and summarized extent by Census Division and by province.

The often quoted rate of increase in saline areas of 10 percent per year (McCracken, 1973; Vander Pluym, 1981, 1978) appears to be too high for use in long term projections, given current trends. The following points are offered for consideration:

1. Rates of secondary salinization are known to vary considerably from year to year, probably reflecting groundwater responses to climatic differences.
2. Annual rates of 10% (and even 16%) have been observed in parts of Alberta during the 1960's over periods of 4 to 10 years (McCracken, 1973).
3. A 30 year observation using air photos from 1950 and 1980 of one of the worst townships in southern Alberta for saline seeps showed a 2.5% annual increase (Agriculture Canada Soil Survey of Warner County, Alberta).
4. Rates of salinization appear to have slowed considerably in all areas in the last few years for unknown reasons (concensus of several soil scientists polled for this study).
5. There is a maximum area (i.e. the discharge zone) that will be affected by seepage and groundwater flow systems which have been disrupted by a shift from native grass cover to a wheat-fallow system may equilibrate.
6. Salinization may, however, continue to spread at high rates in the future, and we are only experiencing a short slow period.

Secondary salinity is increasing in many areas and the rate varies from area to area (as well as from year to year). We have therefore attempted to estimate the amount of salinization over the next 25 years by relating rates to Risk Classes. Areas of Low Risk are considered to have no increase in salinization. Areas of Moderate Risk are predicted to increase 10 percent over 25 years (approximately 0.5 percent per year). Areas of High Risk are predicted to increase by 50 percent over 25 years. These are the areas with abundant saline seeps which we estimate will increase by approximately 2.5 percent per year. These rates of increase compare favorably with the estimate by Rennie (1978) that salinity is increasing by one percent per year on the prairies. This produced a regional treatment of trends which should at least be useful for identifying the areas with growing salinization problems, and should provide a relative ranking of the problem by region.

3.3 Summary of Extent and Severity of Secondary Salinity

Calculations of extent of salinity by Census Division and by province are based on the Saline Soils Map (rear pocket).

3.3.1 Secondary Salinity in Western Canada

The total area of improved land in the grain growing region of western Canada (excluding irrigated areas and areas of predominantly unimproved pasture) affected by secondary salinity is estimated to be approximately 2.6 million acres. We have predicted this will increase to approximately 3.2 million acres in 25 years, representing a mean annual increase of 24,000 acres (Table 3.2). This increase is not distributed evenly over the prairies, as areas with high risk will have much greater increases than the regional average. The areas where the most severe salinization will occur are indicated as High Risk Class areas on the Saline Soils Map, and are the areas that rank highest on an annual cost per improved acre basis (Figure 3.1 and Table 3.7). The province with the largest acreage of secondary salinity is Saskatchewan, but parts of Alberta and Manitoba have the most intensive problems on a Census Division level.

Table 3.2
SUMMARY OF IMPROVED LAND IN THE GRAIN GROWING REGION
OF WESTERN CANADA AFFECTED BY SECONDARY SALINITY
(millions of acres)

Province	Secondary Salinity 1984	Secondary Salinity 2008	Annual Increment
Alberta & B.C. Peace	.941	1.15	.008
Saskatchewan	1.54	1.93	.016
Manitoba	.086	.086	0
Western Canada	2.57	3.17	.024

3.3.2 Secondary Salinity in Alberta

Various estimates of the amount of secondary salinity in Alberta have been made (Vander Pluym, 1981) but comprehensive map-based data are not available for the entire province. A map of secondary salinity in southern Alberta has recently been prepared (Sommerfeldt and Paziuk, Ag. Canada, Lethbridge) but was not available in time for this study. The data base used was a file map of Dryland Seepage and Salinity of part of southern Alberta, prepared by Alberta Environment, Earth Sciences Division (ca. 1973). This map was interpreted using Ballantyne's legend (from Saskatchewan) to estimate risk classes and extent.

The proportion of the improved land area of the province affected by secondary salinity is estimated as 0.944 million acres or approximately three percent of the total (Table 3.3). The C.D.'s with the most extensive salinity problems (C.D.'s 1, 2, 3, 4 and 7) in southern and south-western Alberta have approximately six to nine percent of their improved land affected by salinity.

Table 3.3
EXTENT OF SECONDARY SALINITY IN THE GRAIN GROWING REGION OF ALBERTA AND THE B.C. PEACE REGIONS, 1984 AND 2008 (millions of acres)

Census Division	Total Improved Land	Risk Class	Secondary Salinity 1984 % of Improved Land	1984 Acres	2008 Acres
01	1.609	B	1.8	.029	.032
		C	5.7	.092	.138
		Total	7.5	.121	.170
02	2.575	B	4.0	.103	.113
		C	2.7	.070	.104
		Total	6.7	.173	.217
03	1.425	B	4.3	.061	.067
		C	4.3	.061	.092
		Total	8.6	.122	.159
04	1.943	B	4.9	.095	.105
		Total	4.9	.095	.105
05	3.045	B	1.3	.040	.044
		C	2.2	.067	.100
		Total	3.5	.107	.144
06	1.968	C	3.0	.059	.065
		Total	3.0	.059	.065
07	2.986	B	5.9	.044	.048
		Total	5.9	.044	.048
10	3.590	B	4.3	.154	.170
		Total	4.3	.154	.170
11	2.090	B	0.3	.006	.007
		Total	0.3	.006	.007
13	1.963	B	0.1	.002	.002
		Total	0.1	.002	.002
14	0.219	-	nil	nil	nil
15	4.267	B	1.2	.051	.056
		Total	1.2	.051	.056
55(B.C.)	0.932	B	1.2	.010	.011
		Total	1.2	.010	.011
TOTALS	31.8		3%	.944	1.15

This compares to the most recent estimates by Sommerfeldt and Paziuk (Ag. Canada, Lethbridge, pers. comm.) of 1.5 million acres of secondary salinity in southern Alberta - which included unimproved pasture land and irrigation districts. Their inventory recognized secondary salinity of varying severity, as we have also attempted to do. The two estimates compare quite favourably, considering the amount of variance that must be accepted. Our estimate is considerably larger than those of Vander Pluym (1981, 1978) which was used by PFRA (1983) which were not based on systematic inventories.

We have also attempted to estimate the increase in salinity over the next 25 years. Projections were based on Low Risk Class land (refer to Salinity Map - rear pocket) having no increase, acres of salinized Moderate Risk lands increasing by 10 percent; and acres of salinized High Risk Class lands increasing by 50 percent. A total of 1.15 million acres of improved lands is predicted to be affected by secondary salinization by the year 2008. The areas of largest increase are coincident with those that have large amounts of salinity at present (Table 3.3).

3.3.3 Secondary Salinity in Saskatchewan

There have been many estimates made of the extent and rate of increase of secondary salinity in Saskatchewan (Table 3.1). The most recent and most reliable assessment of risk and extent was prepared by Ballantyne (in press). His Salinity Maps of the Agricultural Region of Saskatchewan formed the basis of the following estimates of risk and extent. Interpretation of Ballantyne's maps for an estimation of total improved lands affected by secondary salinity yielded a provincial total of 1.54 million acres (Table 3.4). There is little variability in extent by Census Division, with almost all C.D.'s having three to four percent of improved land affected. The provincial total estimate of 1.54 million acres (Table 3.4) is considerably less than the four million acres estimated by PFRA (1983) using the Vander Pluym et al. (1981) interpretation of Crosson's map (1976) as a primary source. The difference is primarily attributable to the source maps, and the more recent maps by Ballantyne are

Table 3.4
EXTENT OF SECONDARY SALINITY IN THE GRAIN GROWING REGION
OF SASKATCHEWAN, 1984 AND 2008 (millions of acres)

Census Division	Total Improved Land	Risk Class	Secondary Salinity 1984 % of Improved Land	1984 Acres	2008 Acres
01	2.659	B	1.7	.045	.050
		C	2.1	.056	.084
		Total	3.8	.101	.134
02	3.025	B	0.9	.027	.030
		C	3.2	.097	.145
		Total	4.1	.124	.175
03	3.238	B	1.4	.045	.050
		C	1.8	.058	.087
		Total	3.2	.103	.137
04	2.290	B	1.9	.043	.048
		C	1.1	.025	.038
		Total	3.0	.068	.086
05	2.690	B	1.5	.040	.044
		C	1.6	.043	.064
		Total	3.1	.083	.108
06	3.633	B	1.9	.069	.076
		C	0.7	.025	.038
		Total	2.6	.094	.114
07	3.279	B	1.8	.059	.065
		C	1.2	.039	.059
		Total	3.0	.098	.124
08	3.881	B	1.8	.070	.077
		C	1.1	.042	.064
		Total	2.9	.112	.141
09	2.258	B	2.2	.050	.060
		C	0.9	.020	.030
		Total	3.1	.070	.090
10	2.338	B	2.8	.065	.072
		C	0.4	.009	.014
		Total	3.2	.074	.086

Table 3.4 cont'd
EXTENT OF SECONDARY SALINITY IN THE GRAIN GROWING REGION
OF SASKATCHEWAN, 1984 AND 2008 (millions of acres)

Census Division	Total Improved Land	Risk Class	Secondary Salinity 1984 % of Improved Land	1984 Acres	2008 Acres
11	3.350	B	2.2	.074	.081
		C	1.7	.057	.085
		Total	3.9	.131	.166
12	2.556	B	2.2	.056	.062
		C	0.6	.015	.023
		Total	2.8	.071	.085
13	3.223	B	2.5	.081	.089
		C	0.6	.019	.023
		Total	3.1	.100	.112
14	2.857	B	3.2	.091	.100
		C	0.1	.003	.004
		Total	3.3	.094	.104
15	3.226	B	2.0	.064	.071
		C	1.0	.032	.048
		Total	3.0	.096	.119
16	2.231	B	2.2	.049	.054
		C	0.8	.018	.027
		Total	3.0	.067	.081
17	1.888	B	1.8	.034	.038
		C	1.2	.023	.034
		Total	3.0	.057	.072
18	0.017	B	3.0	.0005	.0005
		C	---	---	---
		Total	3.0	.0005	.0005
PROVINCE	48.6		3.2%	1.54	1.93

considered to be more reliable (D. Acton, D. Anderson, H. Rostad, Sask. Inst. Pedology, pers. comm.).

It is generally believed that salinization is increasing in Saskatchewan, although present estimates of rates are lower than those generally suggested five to 10 years ago (D. Rennie, U. of S., pers. comm.; J. Ellis, Sask. Inst. Pedology, pers. comm.). We have predicted trends over 25 years by relating to the Risk Classes of Ballantyne's maps and assuming that: Low Risk Class soils which are non-saline now will not become salinized; acres of salinized Moderate Risk Class soils will increase by 10 percent in 25 years (approximately 0.5% per year); and acres of salinized High Risk Class soils will increase by 50 percent in 25 years (approximately 1.5% per year). These projections predict a total of 1.93 million acres of improved land affected by secondary salinity by the year 2008.

3.3.4 Secondary Salinity in Manitoba

The total area of saline soil areas with salinity inclusions comprise less than 5% of Manitoba's agricultural land base (Eilers, 1978), and salinity is not considered to be spreading. We have estimated the amount of secondary salinity to be 10 percent of the total saline area based on a concensus of opinion of various soil scientists in Manitoba (as polled by F. Pitura in 1984). The total provincial extent of secondary salinity is estimated at 85,800 acres (Table 3.5). The Census Divisions most severely affected by secondary salinity are 14, 15, 18 and 19. These C.D.'s have from 1.2 to 4.2 percent of total improved lands affected. Other C.D.'s in the province have generally less than 0.5 percent of improved land salinized.

The majority of secondary salinization in Manitoba is associated with toe-slope seeps or increasing size of sloughs, and not the side-hill type of seep of major concern in Alberta and Saskatchewan (R.G. Eilers, Canada - Manitoba Soil Survey; pers. comm.). Toe-slope salinization appears to be aggravated by summerfallowing - which is declining rapidly in Manitoba, therefore the risk of increase in saline areas is minimal.

Table 3.5
EXTENT OF SECONDARY SALINITY IN THE GRAIN GROWING REGION OF MANITOBA, 1984 AND 2008 (millions of acres)

Census Division	Risk Class	% Secondary Salinity	Acres of Secondary Salinity 1984	Acres of Secondary Salinity 2008
01	--	---	---	---
02	--	---	---	---
03	B	0.7	.0089	N/C*
04	--	---	---	---
05	B,C	0.3	.0044	N/C
06	B	0.5	.0032	N/C
07	B	0.3	.0026	N/C
08	B	0.3	.0032	N/C
09	B	0.2	.0013	N/C
10	C	0.4	.0016	N/C
11	--	---	---	---
12	--	---	---	---
13	--	---	---	---
14	B,C	4.2	.0172	N/C
15	B	1.2	.0176	N/C
16	B	0.2	.0016	N/C
17	B	0.6	.0065	N/C
18	B,C	2.3	.0161	N/C
19	B	3.1	.0016	N/C
20-23	--	---	---	---
PROVINCE		0.6	.0858	

* N/C = No Change

3.4 Effects of Salinity on Yields

Effects of salinity on yields varies with severity of salt content, which often ranges considerably within an area. We have assumed a moderate level of salinity (EC = 6) when estimating salinity extent and related it to yield effects (Table 3.6) using regressions developed by Holms (1983). This is a simplistic approach but it is beyond the scope of this project to consider various salinity levels; various depths to salt; interactions of climate; and several other complicating factors. Background information on relationships of severity and yield are summarized in Appendix A.

Table 3.6
GUIDELINES FOR ESTIMATING
THE EFFECTS OF SALINITY ON YIELDS

	Salinity Severity (mS/cm)			
Crop	4	6*	8	10
	--- Relative Productivity (%)** ---			
Wheat (Neepawa)	66	52	37	22
Barley (Bonanza)	81	70	59	49
Canola	62	47	30	14

* A severity level of EC = 6 was used to estimate effects on yields for the cost analysis in this report.

** Relative Productivity assuming no compensating inputs.

Major Data Source: Holm (1983)

3.5 Economic Costs

The methodology developed to cost all soil degradation issues addressed in this study is essentially the following:

Annual Cost = (Total Area Impacted)(Yield Loss)(Crop Value)

Crop value estimates, per improved acre, are developed in Appendix B. The projected area and yield impacts, by Census Division, are described in the preceding.

The resulting calculations are tabulated in detail in Table 3.7 following.

Tables 3.8 - 3.10 are summary tables which project the relative impact of secondary salinity across the Prairies during the next 25 years. These calculations are, at least, generally indicative of the current and projected costs of secondary salinity on the Prairies. And, perhaps even more importantly, this analysis highlights where salinity problems are most acute: Southern Alberta (C.D.'s 1-3), South Central Manitoba (C.D. #14), Northeastern Alberta (C.D. #10), and Southern Saskatchewan (C.D. #2)(Figure 3.1). Man-induced salinity already costs a typical farmer in Southern Alberta in excess of $2,000. per annum.

The implicit rate of growth in the annual cost of salinity to Prairie farmers is also indicated -- about one percent per year.

Table 3.11 following also helps to put the salinity issue into perspective:

- Annual crop losses from salinity on the Prairies are substantial; about $100 million per annum and climbing. This is a relatively modest cost in terms of the total value of Prairie crop production (say 1.5%) but in terms of lost net farm income it is much more important (say 5%). There are also indirect costs.

- In absolute terms, on a Province-wide basis, secondary salinity is most

Table 3.7
SALINITY - ESTIMATED ACTUAL & POTENTIAL COSTS WITHOUT AMELIORATIVE MEASURES, PRAIRIE PROVINCES, BY CENSUS DIVISION, 1984-2008* ($ Thousands Current)

Census Division	Alberta			Saskatchewan			Manitoba		
	1984	1990	2008	1984	1990	2008	1984	1990	2008
1	4389	4833	6165	3592	3885	4765	—	—	—
2	8276	8802	10380	4976	5488	7022	—	—	—
3	4298	4625	5604	3947	4272	5248	625	625	625
4	2814	2888	3110	2396	2555	3031	—	—	—
5	4647	5049	6255	3046	3271	3944	246	246	246
6	2428	2490	2675	3700	3896	4485	154	154	154
7	2288	2341	2499	3630	3871	4594	131	131	131
8	—	—	—	4246	4521	5345	178	178	178
9	—	—	—	2636	2825	3391	80	80	80
10	7337	7528	8100	2911	3029	3382	110	110	110
11	210	218	243	5279	5632	6690	—	—	—
12	—	—	—	3019	3168	3614	—	—	—
13	60	60	60	4312	4442	4831	—	—	—
14	—	—	—	4425	4488	4677	876	876	876
15	1522**	1560**	1672**	4543	4800	5572	788	788	788
16	—	—	—	2800	2947	3388	57	57	57
17	—	—	—	2640	2814	3334	290	290	290
18	—	—	—	10	10	10	577	577	577
19	—	—	—	—	—	—	49	49	49
20,21	—	—	—	—	—	—	—	—	—
Total	38269	40394	46763	62108	65914	77323	4161	4161	4161

* Only refers to actual and potential man-induced salinity.

** The comparable figures for the B.C. Peace area are $335, $343, $388 thousand respectively (not included in the Alberta totals).

Table 3.8
SALINITY - PROJECTED FARM IMPACTS IN ALBERTA AND THE B.C. PEACE AREA WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division*	Annual Cost/ Improved Acre ($ Current)			Annual Cost/Farm** ($ Current)			Rank***			
							Province		Prairies	
	1984	1990	2008	1984	1990	2008	1984	2008	1984	2008
1	2.73	3.00	3.83	2424	2669	3404	3	3	3	3
2	3.21	3.42	4.03	2166	2304	2717	1	1	1	1
3	3.02	3.25	3.93	2118	2279	2762	2	2	2	2
4	1.45	1.49	1.60	1772	1819	1958	6	6	10	-
5	1.53	1.66	2.05	1459	1585	1964	5	5	9	7
6	1.23	1.27	1.36	563	577	620	7	7	-	-
7	.77	.78	.84	593	607	648	8	8	-	-
10	2.04	2.10	2.26	1030	1057	1137	4	4	5	5
11	.10	.11	.12	30	31	35	10	10	-	-
13	.03	.03	.03	11	11	11	-	-	-	-
15	.36	.37	.39	185	189	203	9	9	-	-
55 (B.C.)	.36	.37	.39	179	183	197				
Total Area	1.21	1.28	1.48	694	680	786	-	-	-	-

* Only includes C.D.'s with non-zero values.

** Based on farm numbers in 1980, consistent with the 1981 Census of Agriculture.

*** Ranked according to the annual cost/improved acre where 1 = worst.

Table 3.9
SALINITY - PROJECTED FARM IMPACTS IN SASKATCHEWAN WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division*	Annual Cost/ Improved Acre ($ Current)			Annual Cost/Farm* ($ Current)			Rank**			
							Province		Prairies	
	1984	1990	2008	1984	1990	2008	1984	2008	1984	2008
1	1.35	1.46	1.79	1033	1117	1370	6	3	-	9
2	1.64	1.81	2.32	1398	1542	1973	1	1	6	4
3	1.22	1.32	1.62	1101	1191	1463	10	6	-	-
4	1.05	1.12	1.32	1097	1170	1388	-	-	-	-
5	1.13	1.22	1.47	665	714	861	-	-	-	-
6	1.02	1.07	1.23	697	734	845	-	-	-	-
7	1.11	1.18	1.40	982	1047	1243	-	-	-	-
8	1.09	1.16	1.38	1055	1124	1328	-	-	-	-
9	1.17	1.25	1.50	570	611	733	-	9	-	-
10	1.25	1.30	1.45	791	824	920	9	10	-	-
11	1.58	1.68	2.00	1155	1232	1463	2	2	7	8
12	1.18	1.24	1.41	1003	1052	1201	-	-	-	-
13	1.34	1.38	1.50	1256	1294	1408	7	8	-	-
14	1.55	1.57	1.64	898	911	949	3	6	8	-
15	1.41	1.49	1.73	763	806	935	4	5	-	-
16	1.26	1.32	1.52	750	789	907	8	7	-	-
17	1.40	1.49	1.77	901	960	1138	5	4	-	10
18	.57	.57	.57	323	323	323	-	-	-	-
Province	1.28	1.36	1.59	923	979	1149	-	-	-	-

* Based on farm numbers in 1980, consistent with the 1981 Census of Agriculture.
** Ranked according to the annual cost/improved acre where 1 = worst.

Table 3.10
SALINITY - PROJECTED FARM IMPACTS IN MANITOBA WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division	Annual Cost Improved Acre ($ Current) 1984-2008	Annual Cost/Farm* ($ Current) 1984-2008	Rank ** Province 1984-2008	Rank ** Prairies 1984	Rank ** Prairies 2008
3	.52	237	4	-	-
5	.17	115	10	-	-
6	.25	138	7	-	-
7	.15	82	-	-	-
8	.19	107	9	-	-
9	.15	79	-	-	-
10	.26	177	6	-	-
14	2.12	810	1	4	6
15	.54	281	5	-	-
16	.09	42	-	-	-
17	.25	107	8	-	-
18	.81	273	3	-	-
19	.94	233	2	-	-
Province	.31	141	-	-	-

* Based on farm numbers in 1980, consistent with the 1981 Census of Agriculture.
** Ranked according to the annual cost/improved acre where 1 = worst.

Table 3.11
SALINITY - PROJECTED TOTAL COST ON THE PRAIRIES WITHOUT AMELIORATIVE MEASURES, 1984 - 2008* ($ Million Current)

Year		Alberta**	Saskatchewan	Manitoba	TOTAL PRAIRIES
1984		38.3 (1.3%)	62.1 (1.4%)	4.2 (0.2%)	104.6 (1.2%)
85		38.6	62.7	4.2	105.5
86		39.0	63.4	4.2	106.6
87		39.3	64.0	4.2	107.5
88		39.7	64.6	4.2	108.5
89		40.0	65.3	4.2	109.5
1990		40.4 (1.4%)	65.9 (1.5%)	4.2 (0.2%)	110.5 (1.2)
91		40.7	66.5	4.2	111.4
92		41.1	67.2	4.2	112.5
93		41.5	67.8	4.2	113.5
94		41.8	68.4	4.2	114.4
95		42.2	69.1	4.2	115.5
96		42.5	69.7	4.2	116.4
97		42.9	70.3	4.2	117.4
98		43.2	71.0	4.2	118.4
99		43.6	71.6	4.2	119.4
2000		43.9 (1.5%)	72.3 (1.7%)	4.2 (0.2)	120.4 (1.3%)
01		44.3	72.9	4.2	121.4
02		44.6	73.5	4.2	122.3
03		45.0	74.2	4.2	123.4
04		45.3	74.8	4.2	124.3
05		45.7	75.4	4.2	125.3
06		46.1	76.1	4.2	126.4
07		46.4	76.7	4.2	127.3
08		46.8 (1.6%)	77.3 (1.8%)	4.2 (0.2%)	128.3 (1.4%)
DIRECT NET PRESENT COST***	5%	587	960	59	1606
	10%	378	618	38	1034
	15%	269	440	27	736
TOTAL NET PRESENT NET****	5%	939	1536	94	2569
	10%	605	989	61	1655
	15%	430	704	43	1177

* Percent of crop revenue indicated in brackets.
** Excludes the Peace area of British Columbia.
*** Discount rate = 5%, 10%, and 15%.
**** Direct plus indirect where the GDP multiplier = 1.6 (Underwood McLellan Ltd., 1983).

SALINITY

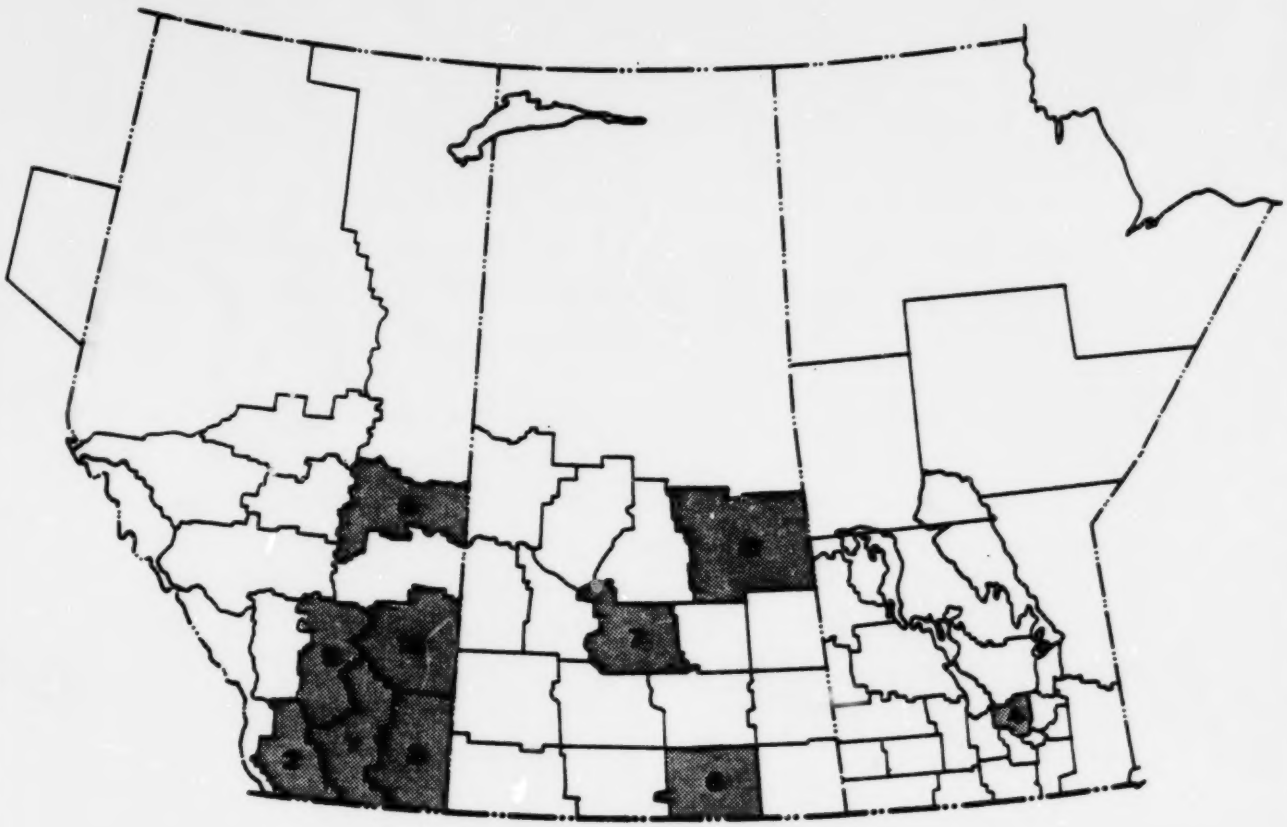

Figure 3.1 Location of census divisions most affected by salinity, ranked by annual cost per improved acre.

severe in Saskatchewan. About 60% of the secondary salinity is in Saskatchewan, 36% in Alberta, and 4% in Manitoba.

- The total cost of secondary salinity on the Prairies is expected to increase by about $500,000 per annum. This is indicative of what could be spent annually (and justified) to arrest further secondary soil salinization on the Prairies; expenditures over-and-above what would be required to reclaim existing saline areas.

- The cumulative cost of secondary salinity over the next 25 years, without amelioration, would be very substantial. At a 10% discount rate, this direct cost will probably exceed $1 billion; direct and indirect costs would likely exceed $1.6 billion. If we assume a 5% discount rate is appropriate, these cumulative costs over 25 years could climb to $1.6 billion and $2.6 billion respectively.

These estimates are somewhat lower than one prior economic study on this topic (PFRA, 1983). But this can largely be traced to the relative magnitude of three physical parameters discussed in detail in the preceding, namely the base acreage which various researchers think is being affected (total vs. secondary), yield impacts, and the corresponding rates of change over time (10%/year vs. 1%/year). The economic parameters utilized in this study are essentially the same as employed previously.

3.6 The Economics of Amelioration

Considerable physical research is currently being undertaken on the control and reclamation of saline soils. The preferred technique seems to be the utilization of excess water in the recharge area and, generally, the following methods of saline control and reclamation (or some combination thereof) have been suggested:

(1) Use of deep rooted perennial crops to dry out the soil profile;
(2) More intensive cropping with the gradual elimination of summerfallow in saline-prone areas;
(3) Surface and subsurface drainage where feasible;
(4) Utilization of effective snow management practices;
(5) The planting of salt tolerant crops.

The on-farm economic feasibility (or persent practicality) of adopting these practices, however, is only now receiving some of the attention it requires.

With respect to the current economics of dryland salinity control and reclamation, perhaps the most thorough analysis in Western Canada has been conducted by Alberta Agriculture in support of their on-going Agricultural Land Base Study (Govindasamy, August 1984). More specifically, this benefit-cost analysis assesses the impact of vegetative control of dryland salinity on crop production and farm income, given the following assumptions:

(1) The analysis was based on a simulated dryland farming operation in Warner County with 1,110 cultivated acres. Approximately 77 acres were assumed to be severely salinized.

(2) A 10 acre centrally located circular saline seep on a quarter section was assumed for ease of calculation. Before reclamation, the seep area was totally unproductive and the size of the seep was assumed to increase by 10% annually. The recharge area was assumed to be five times as large as the discharge area.

(3) Before vegetative reclamation, the producer was on a 50/50, spring wheat/fallow rotation. Both the seep area and the 50 acres of recharge area were seeded to alfalfa with barley as the nurse crop. The rest of the quarter section (100 acres) remained on a spring wheat/fallow rotation.

(4) Reseeding of alfalfa was assumed necessary in the second year due to poor germination and other problems of establishment.

(5) After six years, it was assumed that both recharge and discharge areas were completely desalinized and were continuously cropped with a spring wheat/barley/rapeseed rotation.

But even given this rather optimistic soil salinity reclamation scenario, the resulting benefit-cost ratio (at a 5% discount rate) was very marginal at 1.11. And given the grain prices assumed in other sections of this report, in conjunction with a discount rate of 10% per annum, this ratio is more likely to be about 0.6.

Or, in other words, at this point in time, it is very unlikely that farmers could generally afford to adopt (in the short-run) even this relatively optimistic salinity reclamation procedure on their own farms. And this is still largely ignoring the disincentives of:

1. Expected financial losses during the first two years of say, $50/acre/year,
2. The need for a radical change in cropping patterns and enterprise selection (since the alfalfa area = 5 - 10 times the seepage area), and
3. Market limitations.

In short, these results strongly suggest that if large scale vegetative reclamation of dryland salinity is to be encouraged under prevailing agricultural conditions, public financial assistance will most likely be required.

On the other hand, there is at least some evidence to suggest that the economics of salinity control and reclamation on irrigated lands are somewhat better. For example, Birch (1983) found that the B/C ratio associated with the drainage of saline soils was about 1.25. But, again, utilizing the prices employed elsewhere in this study, and a discount rate of 10 percent/annum, this ratio would most likely drop to, say, 0.70. Thus, it is our professional judgement that this investment would also find only very limited acceptance in the farm community at this point in time.

In general, however, these empirical results are not definitive. At the same time, it is also readily apparent that a comprehensive economic analysis of various recommended reclamation practices would be difficult because the cause and control of salinity can vary significantly from farm to farm and area to area across the Prairies. The present lack of data on reclamation rates and related crop yields for various Prairie conditions further compounds the problem.

3.7 Research and Policy Implications

The research documented in the preceding generally underlines many of the outstanding research needs with respect to saline soils in Western Canada. Many of these requirements have already been itimized: (Western Provincial Conf., 1982).

A) TOP PRIORITY

1) Document the problem:
   - extent and location
   - economic importance
   - rate of change
   - identify areas potentially susceptible to salinization
2) Develop models of salt and water flux as related to landscape.
3) Evaluate the effect on salinity of soil and water management practices in the recharge area.

4) Study physical-chemical processes of salt and water movement.
5) Develop a greater understanding of the geology and hydrology of affected areas.
6) Determine micro- and macro-climatic effects on salinization processes.
7) Develop techniques of accurately identifying recharge areas in Western Canada.
8) Assess the economics of recommended control practices.

B) SECOND LEVEL PRIORITY
1) Determine environmental impact of seep and drainage discharge.
2) Develop land management practices for discharge areas.
3) Evaluate sources and suitability of amendments for saline soil reclamation.
4) Determine crop tolerance to salinity under growing conditions prevalent in Western Canada.
5) Undertake plant breeding and selection programs for salt tolerance.
6) Determine the water management requirement for crop production on irrigated saline soils.

C) THIRD LEVEL PRIORITY
1) Determine the impact of salinity on structures, roads, etc.
2) Determine the effect of salinity on the health of humans, domestic animals, and wildlife.
3) Modify or develop instruments for salinity measurements.
4) Improve analytical techniques and methods.

In an economic context, what is really required is accurate on-farm data or, at least, very carefully constructed "representative" on-farm data. The specific economic data needs are: (a) improved salinity-crop yield relationships, and (b) specific reclamation-crop yield relationships. Both are required in a spatial and temporal context. These research needs are essentially a public responsibility.

The present analysis also implies that in the case of salinity control and reclamation, government may also have to intervene with some form of on-farm assistance.

The rationale for these public expenditures would not be novel. The farmers' time frame is too short; his short-term financial needs are too great for him to adopt the practices required to sustain the long-term productivity of the land. At the farm level, existing salinity costs can periodically be capitalized into lower private land values. Moreover, a growing salinity problem may simply go undetected because the changes are so slow or because they are masked by input substitution, e.g. more fertilizer.

In the case of salinity, the justification for public assistance is even greater because of the existence of negative externalities. A farmer may, in fact, generate a salinity problem on his neighbour's land -- yet he has no economic incentive to correct the salinity problem in a discharge area located on his neighbour's property.

4.0 SOIL EROSION

4.1 Overview

Erosion by water is perhaps the most-recognized form of soil degradation, and is considered by most people to be the issue of greatest concern in soil conservation across Canada (AIC, 1983; Bentley and Leskiw, 1983; Bentley, 1981). Wind erosion has been identified as a major concern in the "Palliser Triangle" since the 1920's, and has been a recurring problem in the 1980's, which has attracted much public attention. Water erosion has generally not been considered to be a large problem in the semi-arid parts of Western Canada (Coote et al., 1981; Toogood, 1963), but recent work in some of the driest areas has shown that two-thirds of the soil loss has been by water eorsion (W. Pettapiece, Agriculture Canada, pers. comm.). Water erosion occurs sporadically but is often a recurrent problem in the same location, resulting in large total losses (DeJong et al., 1983; Mermut et al., 1983; Chin, 1972). Many soil landscapes throughout the Prairies have experienced total topsoil loss from 30 to 50 percent of their area (as interpreted from various soil survey reports). This range of eroded surface percentage is similar in each of the Brown, Dark Brown, Black and Gray Soil Zones, in Alberta and Saskatchewan. The amount of eroded area correlates to landform, soil texture, soil type and management practices, which forms the basis we have used to estimate risk and extent of erosion.

Erosion removes part or all of the topsoil, and often the upper part of the subsoil, resulting in a soil with low organic matter, poor tilth, low water holding capacity, poor nutrient supply power and lower capability for production. This results in poorer growth and greater risk for more erosion. The productivity of these soils cannot be replaced completely (perhaps only 75 percent) with fertilizers and other ameliorative practices. The actual effects on yields, assuming no compensating inputs, on different soil types is not known (Anderson and Gregorich, 1983).

Water erosion on glacial landscapes with poorly integrated drainage systems, which characterize much of the Prairies, results in redistribution of topsoil in a small area, often within the same field. This results in less damage to neighbours fields and public structures, and less sedimentation of river systems than occurs in landscapes with long, planar slopes and integrated drainage systems. This feature also makes erosion less visible to the public. The Peace River Region is somewhat of an exception to this pattern, with many long, planar slopes and examples of off-farm damages by water erosion, which are quite visible.

4.2 Estimation of Risk, Extent and Severity

The extent and severity of soil erosion in Western Canada has not been documented - an information gap that has been identified many times (PFRA, 1983; Coote, 1983; Bentley, 1981; Goettel et al., 1981; Johnson, 1961).

Recent research in Saskatchewan by DeJong et al. (1983) identified historic losses of 20 to 60 kg soil/m2 from upper slope positions and deposition rates of 25 to 80 kg/m2 on lower slopes, in Dark Brown and Black soil landscapes. Mermut et al. (1983) identified average annual losses of 0.5 cm over the past 70 years (a total historic loss of 35 cm) from clayey soils on 7.5 percent slopes in southwestern Saskatchewan.

Quantitative assessments of historic soil losses, monitoring of current losses, and estimates of future losses on a regional basis are urgently needed but, due to an inadequate data base, can only be roughly estimated at this time. We have estimated erosion risk and extent and severity of historic erosion using the limited amount of data available and making several extrapolations and assumptions. The resulting Soil Erosion Map (rear pocket) and derived data of extent and severity by Census Division are therefore only rough estimates with a low confidence level. We feel, however, that these are the best estimates available, and are reasonable (and perhaps conservative).

Soil erosion rates (and risk) vary with climatic factors, topographic factors, and soil surface factors, but essentially a bare soil surface is much more erodible than one that is covered with plant growth. Cropping systems that include summerfallowing (the soil is cultivated and not cropped for one year) increase erosion risk; and continuous cropping or minimum tillage systems reduce risk. Risk of water and wind erosion, with consideration for cropping practices, was assessed by Coote et al. (1981) and ranked nationally on a relative scale (low, moderate, high). They rated most of western Canada as having moderate risk for water erosion and low to high risk for wind erosion. As with other degradation issues, management is a major factor determining the rate of erosion of cultivated lands.

Changing cropping systems will have considerable impact on erosion rates. In Manitoba the shift to continuous cropping reduces risk but the increase in row crops increases risk in some areas. In Alberta and Saskatchewan the decreasing amount of summerfallow in the Black and Dark Brown Soil Zones will lower risk. There has also been some reduction in amounts of fallow in the Brown Zone (moreso in Alberta than in Saskatchewan) and this trend will probably continue. However, the trend to larger field sizes, reduction of strip cropping, more incorporation of herbicides (more cultivation passes), and increased acreage of Canola which requires a fine seedbed, all serve to increase risk.

The Erosion Map legend indicates three Erosion Risk Classes (low, moderate, high), four Eroded Extent Classes (N= < 1%, 1 = < 15%, 2 = 15 - 40%, 3 = >40%) and an indicator of trend (x = static, y = increasing). The Erosion Risk Classes consider physical and management factors and are best considered to be province-specific rather than being comparable across western Canada due to the considerable differences in cropping systems across the prairie region. The estimates of eroded extent attempt to identify the amount of soil surface area from which topsoil has been totally or partially removed - expressed as acres of total removal. In Alberta, Saskatchewan and the B.C. Peace the areas of partial removal have been weighted and expresses as part of the total removal area. In Manitoba the impact of erosion is primarily partial removal - but the

estimates have been proxied as acres with total removal for comparison to the other provinces.

We have used the Risk Classes and anticipated cropping systems to predict the amount of erosion that will occur over the next 25 years. The assumption used was that Low Risk Class land will not erode appreciably, Moderate Risk Class land will have a 10 percent increase in erosion; and High Risk Class lands will have a 30 percent increase.

4.3 Summary of Erosion Estimates

4.3.1 Soil Erosion in Western Canada

Our estimate of the amount of Improved Land within the grain growing region of western Canada that has suffered total topsoil loss is 12.8 million acres, which is equal to approximately 14 percent of the total (Table 4.1). The areas of loss are primarily upper slope positions in hummocky, rolling and undulating landscapes, but fairly level soils have also lost topsoil by wind and water erosion. The estimate of acres with total topsoil loss has been weighted to include acres with partial loss. The amount of eroded land is projected to increase to 15.5 million acres (approximately 17%) in the next 25 years. The mean annual increase is approximately 100,000 acres.

Table 4.1
SUMMARY OF EROSION RISK AND HISTORIC AND
PROJECTED EROSION IN WESTERN CANADA (millions of acres)

	Acres of Risk Class			Acres and % of Improved Land Eroded	
	Low	Med.	High	1984	2008
B.C. Peace	--	--	.932	0.14 (15%)*	0.15 (16%)
Alberta	5.23	7.61	18.1	4.48 (14.4%)**	5.4 (18%)
Saskatchewan	5.64	33.0	10.0	5.50 (11.3%)	6.6 (14%)
Manitoba	1.50	7.99	4.11	2.68 (19.7%)	3.4 (25%)
Western Canada Improved Lands	12.4	48.6	33.1	12.8 (13.7%)	15.5 (16.6%)

* Percentage of Improved Land in C.D. 55.
** Percentage of Improved Land in province.

4.3.2 Erosion in Alberta and the British Columbia Peace Area

Soil erosion in Alberta (excluding the Peace River area) typically consists of loss of topsoil and often part of the subsoil from upper slope positions on hummocky, rolling, and undulating landscapes. The material that is removed is usually deposited on adjacent lower slope positions. This results in little off-farm damage in most cases. Soil is lost as a result of wind and water erosion throughout the province. Wind erosion causes greater losses in the southern part of the province than in central or northern regions; but the importance of water erosion in the semi-arid south has often been underestimated. The majority of losses occur as a result of intense thunderstorms, spring runoff, and severe windstorms.

In the Peace River area of Alberta and B.C. the landscapes have predominantly long, gentle slopes; resulting in transport of runoff water and sediments over long distances. This can result in considerable off-farm damages to neighbouring farms and public facilities, and increases the sediment load in river systems. Due to the nature of the landscape and erosion processes the Peace area is the most difficult to estimate historic erosion losses. Measurement of current losses and risk are being done by Van Vliet (Ag. Canada, Vancouver) and Chanasyk (U. of Alberta) but results are preliminary and do not document historic losses.

The total area of Improved Land estimates to have total topsoil loss (weighted to include partial loss) due to historic erosion is approximately 4.5 million acres, which is 14 percent of the total (Table 4.2). Census Divisions 1, 3, 7 and 15 are above the provincial average with C.D. #15 (Peace River area) being the highest. These Census Divisions also have the greatest extent of High Risk Class land.

Table 4.2
EROSION - SUMMARY OF RISK, EXTENT AND RANKING
OF CENSUS DIVISIONS IN ALBERTA AND THE B.C. PEACE

Census Division	RISK CLASS millions of acres Low	Mod.	High	% of Improved Land Eroded, 1984	Millions of Acres Eroded 1984	2008	Rank by % Eroded Province
1	--	.277	1.33	16.4	.264	.339	3
2	--	1.17	1.40	13.2	.340	.424	7
3	.197	.148	1.08	21.4	.304	.387	2
4	--	.664	1.28	12.0	.233	.294	10
5	1.43	.382	1.23	14.4	.438	.533	6
6	1.11	.862	--	7.3	.144	.150	-
7	--	--	2.99	16.2	.484	.629	4
8	1.23	.128	.715	6.5	.135	.173	-
9	--	.016	--	7.5	.001	.001	-
10	.933	.329	2.33	9.5	.342	.443	-
11	.326	.975	.788	12.9	.269	.335	8
12	--	1.04	.140	9.6	.113	.124	-
13	--	1.41	.552	12.4	.243	.296	9
14	--	.210	.009	8.2	.018	.020	-
15	--	--	4.27	25	1.06	1.17	1
55 (B.C.)	--	--	.932	15	.140	.153	5
TOTAL					4.52	5.47	

4.3.3 Erosion in Saskatchewan

Historic soil erosion has caused considerable soil degradation throughout the province, and is thought to be an increasing problem in the Brown and Dark Brown Soil Zones - a reflection of farming practices and physical properties.

Most improved land in Saskatchewan was rated as having moderate or high erosion risk. The risk classes correlate directly to amounts of historic loss with higher risk soils having greater amounts of erosion. Sandy textured soils have high risk and are extensively eroded in the Brown Soil Zone where they are susceptible to wind and water erosion, but have lower risk in the Black Soil Zone where wind erosion is of lesser magnitude. Clayey textured soils have high risk when they occur on fairly steep or long slopes, and the amount of historic loss does not vary much by soil zone. A correlation of soils, landforms and slope classes to historic erosion losses and risk class is presented in Appendix A.

The landscapes with highest risk and the most severe historic erosion have hummocky or rolling surface form. The soils on the upper slope positions are eroded, and the soil has been deposited on the lower slopes with little transport of soil over long distances due to the lack of integrated drainage systems. This results in mostly on-farm damage with little public visibility, and generally little off-farm damage.

The total amount of improved land estimated to be eroded is 5.5 million acres, or approximately 11 percent of the improved land base. Census Divisions that are above the provincial percentage are 3, 4, 7, 8, 12, 16 and 17, with C.D.'s 3 and 4 being the highest at approximately 20 percent (Table 4.3).

The eroded acres are predicted to increase to 6 million acres (approximately 14%) in 25 years, with the worst areas being the same ones that are presently the most eroded.

Table 4.3
EROSION - SUMMARY OF RISK, EXTENT AND RANKING
OF CENSUS DIVISIONS IN SASKATCHEWAN

Census Division	RISK CLASS millions of acres Low	Mod.	High	% of Improved Land Eroded, 1984	Millions of Acres Eroded 1984	2008	Rank by % Eroded Province
1	.931	1.67	.053	10.5	.279	3.16	9
2	1.91	.121	.998	6.4	.193	.204	-
3	--	2.33	.907	20.9	.677	.819	1
4	--	1.79	.504	20.5	.470	.546	2
5	--	2.69	--	7.5	.202	.222	-
6	.654	2.98	--	7.5	.272	.345	-
7	.131	2.39	.754	13.0	.426	.518	5
8	--	.388	3.49	14.4	.559	.721	3
9	--	2.19	.068	8.1	.183	.205	-
10	--	2.03	.304	9.8	.229	.267	10
11	--	3.28	.067	9.6	.322	.360	-
12	--	2.20	.358	11.8	.302	.359	7
13	1.26	.870	1.10	11.3	.365	.432	8
14	.371	2.48	--	7.5	.215	.273	-
15	.387	2.71	.129	8.3	.268	.299	-
16	--	1.65	.580	12.5	.279	.337	6
17	--	1.19	.699	13.9	.263	.324	4
18	--	.018	--	7.5	.001	.002	-
TOTAL					5.50	6.55	

4.3.4 Erosion in Manitoba

Erosion is the soil degradation process of greatest concern in Manitoba, with both water and wind erosion being important. Management practices are the prime factors to consider in rating risk and trend of erosion. The continuing shift to row crops (corn, potatoes, beans) in areas of high risk will result in increased soil losses. This increasing trend is partially offset provincially by a continual decrease in the amount of summerfallow. The amount of summerfallow in the province has decreased from approximately 13 percent in 1981 to approximately eight percent of the agricultural land base in 1984. The amount of fallow will probably continue to decline slightly, although it is already at the level predicted for 1990 in the Canada Grains Council report (1982).

Wind erosion usually occurs at or just before seeding time when a bare soil surface is exposed. Continuous cropping of soils on the lacustrine plains has dramatically reduced the risk of wind erosion.

The amount of land affected by historic erosion (on a total topsoil loss basis) is approximately 2.7 million acres (Table 4.4) or approximately 20 percent of the total improved land base. This is predicted to increase to 3.4 million acres (24%) in 25 years.

The greatest erosion risk appears to be in Census Divisions 7 and 8 where row cropping is increasing on sandy textured soils (Table 4.4). A 20 percent increase in eroded acres is predicted in these areas over the next 25 years.

Table 4.4
EROSION - SUMMARY OF RISK, EXTENT
AND RANKING OF CENSUS DIVISIONS IN MANITOBA

Census Division	RISK CLASS millions of acres Low	Mod.	High	% of Improved Land Eroded, 1984	Millions of Acres Eroded 1984	2008	Rank by % Eroded Province
1	.180	.052	.026	22.1	.057	.063	7
2	--	.370	.303	32.1	.216	.237	4
3	--	.904	.301	20.2	.243	.267	9
4	--	.043	.808	40.0	.340	.340	2
5	--	.891	.594	19.0	.283	.283	10
6	--	.407	.219	15.5	.097	.096	-
7	--	.448	.448	21.7	.194	.233	8
8	--	.233	.699	45.8	.427	.512	1
9	.027	.292	.212	28.5	.151	.166	5
10	--	.420	--	13.6	.057	.566	-
11	--	--	--	--	--	--	-
12	.015	.263	.015	12.0	.035	.035	-
13	.250	.013	.073	3.0	.008	.008	-
14	.165	.248	.033	11.1	.046	.046	-
15	--	1.39	.230	3.3	.048	.051	-
16	--	.629	--	9.8	.065	.068	-
17	--	.921	--	18.0	.207	.218	-
18	--	.143	--	3.8	.027	.027	-
19	.044	.008	--	36.5	.019	.019	3
20	.180	.270	.150	26.8	.161	.170	6
21	--	--	--	--	--	--	-
TOTAL					2.68	3.40	

4.4 Effects of Erosion on Yields

Effects of erosion on yields also had to be estimated, as data for western Canada are almost nonexistent. Recent data from a small number of research plots in western Canada and the U.S. (Rennie et al., 1983, 1982; Ives and Shaykewich, 1983; Spratt, 1972; Lindwall, 1980; Pimental et al., 1976; Lyles, 1975) were used to produce an estimate of effects on yields (Table 4.5) on various soil types. We then related the amount of eroded land to the mix of soil types and the mix of crops within a C.D. to estimate yield losses.

Table 4.5
ESTIMATED EFFECTS OF EROSION ON YIELDS

Soil / Crop	Amount of Topsoil Eroded		
	100% loss*	50% loss*	Not Eroded
	----- Relative Productivity (%) -----		
Brown Chernozemics:			
Wheat	50	80	100
Barley	50	80	100
Dark Brown-Black Chernozemics:			
Wheat	70	90	100
Barley	70	90	100
Canola	50	80	100
Gray and Dark Gray Luvisols:			
Wheat	40	70	100
Barley	40	70	100
Canola	20	50	100
Solonetzic Soils:			
Wheat	10	40	100
Barley	10	40	100
Canola	0	30	100

* Estimates of historic erosion are expressed as acres of land with total topsoil removal. Lands with partial topsoil removal were weighted (on an equivalent yield reduction basis) and proxied as acres of total removal.

4.5 Economic Costs

The methodologoy utilized to quantify the on-going and future costs of erosion on the Prairies is identical to that described in Sections 3.5 and 5.5.

The basic calculations are provided in Table 4.6 following.

The estimates in Table 4.6 are translated into costs per acre and costs per farm in accompanying Table 4.7 - 4.9 by C.D. and by province. The costs currently range from about 50 cents/improved acre (in parts of Manitoba) to about $14.00/improved acre in the Peace Country (Alta.) NW Saskatchewan (C.D. #17) is also relatively bad (Figure 4.1). Where the erosion is most severe (and projected to worsen), the costs/farm already exceed $7,000 per year.

Table 4.10 provides the reader with a projected cost summary for the Prairies. About 90% of annual erosion costs are incurred by farmers in Alberta and Saskatchewan - in about equal proportions. Costs of erosion, annually, are presently in excess of 7% of the total value of crop production in Alberta; almost 5% in Saskatchewan. And without preventive measures these percentages are expected to climb. This translates into a net farm income loss which is even more alarming: perhaps a 20 - 25% loss in net farm income from crop production in Alberta and 15 - 20% in Saskatchewan.* In some Census Divisions, losses from erosion are even greater. In both an absolute and relative sense, these estimates (albeit imperfect) should, at the very least, put this particular soil degradation issue into context. Historic and on-going soil erosion, in total, is the most serious single resource degradation issue facing Prairie agriculture today.

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* This assumes, as elsewhere in this report, that incremental gross revenues translate directly into changes in net farm income. That is, it is being assumed that there are no offsetting incremental costs.

Table 4.6
EROSION - ACTUAL & POTENTIAL COSTS WITHOUT AMELIORATIVE MEASURES, PRAIRIE PROVINCES, BY CENSUS DIVISION, 1984-2008
($ Thousands Current)

Census Division	Alberta/B.C.			Saskatchewan			Manitoba		
	1984	1990	2008	1984	1990	2008	1984	1990	2008
1	11115	11904	14270	5043	6010	8912	796	816	875
2	14417	15312	17995	7899	8013	8356	3968	4067	4365
3	8595	9179	10931	27406	27840	29140	5509	5647	6059
4	8521	9069	10714	17606	18325	20483	7089	7089	7089
5	13774	14513	16729	5125	5253	5636	5063	5063	5063
6	5157	5215	5390	6969	7432	8822	1448	1448	1448
7	25399	27305	33024	15492	17236	22469	3359	3527	4031
8	6526	6990	8381	22635	24278	29205	8265	8678	9918
9	39	38	40	5757	5929	6446	2947	3021	3242
10	16410	17631	21293	7059	7354	8239	1204	1204	1204
11	10950	11622	13638	8632	8888	9657	--	--	--
12	6279	6436	6908	8298	8780	10225	610	610	610
13	12509	13175	15171	13182	13787	15600	147	147	147
14	806	830	900	13933	14894	17775	783	783	783
15	59423	60909	65365	14392	14809	16058	739	748	776
16	--	--	--	13792	14518	16696	744	753	781
17	--	--	--	17082	18075	21053	3100	3139	3255
18	--	--	--	53	54	56	335	335	335
19	--	--	--	--	--	--	223	223	223
20	--	--	--	--	--	--	2554	2586	2682
21	--	--	--	--	--	--	--	--	--
55	8860	9065	9682						
TOTAL	208778	219193	250431	210355	221475	254828	48883	49884	52886

Table 4.7
EROSION - PROJECTED FARM IMPACTS IN ALBERTA AND THE B.C. PEACE AREA WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division	Annual Cost/ Improved Acre ($ Current)			Annual Cost/Farm* ($ Current)			Rank**			
							Province		Prairies	
	1984	1990	2008	1984	1990	2008	1984	2008	1984	2008
1	6.91	7.40	8.87	6137	6573	7880	4	4	9	7
2	5.60	5.95	6.99	3774	4008	4711	7	7	-	-
3	6.03	6.44	7.67	4236	4524	5387	5	6	-	-
4	4.38	4.67	5.51	5366	5711	6747	-	-	-	-
5	4.52	4.77	5.49	4325	4557	5252	-	-	-	-
6	2.62	2.65	2.74	1196	1209	1250	-	-	-	-
7	8.51	9.14	11.06	6583	7078	8560	3	2	5	3
8	3.14	3.36	4.03	1164	1247	1495	-	-	-	-
9	2.29	2.35	2.47	544	559	588	-	-	-	-
10	4.58	4.91	5.93	2303	2475	2989	10	9	-	-
11	5.24	5.56	6.53	1560	1656	1943	9	8	-	-
12	5.34	5.47	5.87	2001	2051	2201	8	10	-	-
13	6.37	6.71	7.73	2299	2421	2788	6	5	10	10
14	3.68	3.79	4.11	985	1015	1100	-	-	-	-
15	13.93	14.27	15.32	7212	7393	7934	1	1	1	1
55 (B.C.)	9.50	9.72	10.39	4735	4845	5175	2	3	2	5
Total Area	6.55	6.87	7.85	3484	3658	4179				

* Based on farm numbers in 1981, consistent with the 1981 Census of Agriculture.
** Ranked according to the annual cost/improved acre where 1 = worst.

Table 4.8
EROSION - PROJECTED FARM IMPACTS IN SASKATCHEWAN WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division	Annual Cost/ Improved Acre ($ Current)			Annual Cost/Farm* ($ Current)			Rank**			
							Province		Prairies	
	1984	1990	2008	1984	1990	2008	1984	2008	1984	2008
1	1.90	2.26	3.35	1450	1728	2562	-	-	-	-
2	2.61	2.65	2.76	2219	2251	2348	-	-	-	-
3	8.46	8.60	9.00	7642	7764	8126	2	2	6	6
4	7.69	8.00	8.94	8061	8390	9379	3	3	8	9
5	1.91	1.95	2.10	1119	1146	1230	-	-	-	-
6	1.92	2.05	2.43	1313	1400	1662	-	-	-	-
7	4.72	5.26	6.85	4190	4662	6078	7	6	-	-
8	5.83	6.25	7.52	5625	6033	7258	5	4	-	-
9	2.55	2.63	2.85	1244	1282	1393	-	-	-	-
10	3.02	3.15	3.52	1919	1999	2240	-	-	-	-
11	2.58	2.65	2.88	1888	1944	2112	-	-	-	-
12	3.25	3.44	4.00	2757	2917	3397	10	10	-	-
13	4.09	4.28	4.84	3841	4017	4545	9	9	-	-
14	4.88	5.21	6.22	2827	3022	3607	6	7	-	-
15	4.46	4.59	4.98	2416	2486	2695	8	8	-	-
16	6.28	6.51	7.48	3694	3888	4471	4	5	-	-
17	9.05	9.57	11.15	5830	6169	7185	1	1	3	2
18	3.00	3.05	3.17	1710	1742	1806	-	-	-	-
Province	4.32	4.55	5.24	3125	3290	3785	-	-	-	-

* Based on farm numbers in 1981, consistent with the 1981 Census of Agriculture.
** Ranked according to the annual cost/improved acre where 1 = worst.

Table 4.9
EROSION - PROJECTED FARM IMPACTS IN MANITOBA WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division	Annual Cost/ Improved Acre ($ Current)			Annual Cost/Farm* ($ Current)			Rank**			
							Province		Prairies	
	1984	1990	2008	1984	1990	2008	1984	2008	1984	2008
1	3.08	3.17	3.40	769	788	845	10	10	-	-
2	5.89	6.04	6.48	1873	1920	2061	3	3	-	-
3	4.57	4.69	5.03	2091	2144	2300	5	5	-	-
4	8.33	8.33	8.33	4481	4481	4481	2	2	7	8
5	3.41	3.41	3.41	2366	2366	2366	9	9	-	-
6	2.31	2.31	2.31	1297	1297	1297	-	-	-	-
7	3.75	3.94	4.50	2105	2210	2526	8	6	-	-
8	8.87	9.31	10.64	4991	5240	5989	1	1	4	4
9	5.56	5.70	6.11	2927	3000	3219	4	4	-	-
10	2.87	2.87	2.87	1936	1936	1936	-	-	-	-
11	--	--	--	--	--	--	-	-	-	-
12	2.09	2.09	2.09	577	577	577	-	-	-	-
13	0.56	0.56	0.56	151	151	151	-	-	-	-
14	1.89	1.89	1.89	724	724	724	-	-	-	-
15	0.50	0.51	0.53	284	287	277	-	-	-	-
16	1.12	1.14	1.18	546	553	573	-	-	-	-
17	2.69	2.73	2.83	1145	1159	1202	-	-	-	-
18	0.47	0.47	0.47	158	158	158	-	-	-	-
19	4.29	4.29	4.29	1062	1062	1062	6	8	-	-
20	4.25	4.30	4.46	1930	1955	2027	7	7	-	-
Province	3.59	3.67	3.89	1680	1694	1798	-	-	-	-

* Based on farm numbers in 1981, consistent with the 1981 Census of Agriculture.
** Ranked according to the annual cost/improved acre where 1 = worst.

Table 4.10
EROSION - PROJECTED TOTAL COST ON THE PRAIRIES WITHOUT AMELIORATIVE MEASURES, 1984 - 2008* ($ Million Current)

Year	Alberta**	Saskatchewan	Manitoba	TOTAL PRAIRIES
1984	208.8 (6.8%)	210.4 (4.9%)	48.9 (2.9%)	468.1 (5.2%)
85	210.5	212.2	49.1	471.8
86	212.2	214.1	49.2	475.5
87	214.0	215.9	49.4	479.3
88	215.7	217.8	49.6	483.1
89	217.5	219.6	49.7	486.8
1990	219.2 (7.1%)	221.5 (5.1%)	49.9 (3.0%)	490.6 (5.4%)
91	220.9	223.3	50.1	494.3
92	222.7	225.2	50.2	498.1
93	224.4	227.0	50.4	501.8
94	226.1	228.9	50.6	505.6
95	227.9	230.7	50.7	509.3
96	229.6	232.6	50.9	513.1
97	231.3	234.4	51.1	516.8
98	233.1	236.3	51.2	520.6
99	234.8	238.2	51.4	524.4
2000	236.5 (7.7%)	240.0 (5.6%)	51.6 (3.1%)	528.1 (5.8%)
01	238.3	241.9	51.7	531.9
02	240.0	243.7	51.9	535.6
03	241.8	245.6	52.1	539.5
04	243.5	247.4	52.2	543.1
05	245.2	249.3	52.4	546.9
06	247.0	251.1	52.6	550.7
07	248.7	253.0	52.7	554.4
08	250.4 (8.2%)	254.8 (5.9%)	52.9 (3.1%)	558.1 (6.2%)
DIRECT NET PRESENT COST***	5% 3124	3160	706	6990
	10% 2012	2035	455	4502
	15% 1433	1449	324	3206
TOTAL NET PRESENT NET****	5% 4998	5056	1130	11184
	10% 3219	3256	728	7203
	15% 2293	2318	518	5129

* Percent of crop revenue indicated in brackets.
** Includes the Peace area of British Columbia.
*** Discount rate = 5%, 10% and 15%.
**** Direct plus indirect where the GDP multiplier = 1.6 (UMA, 1983).

EROSION

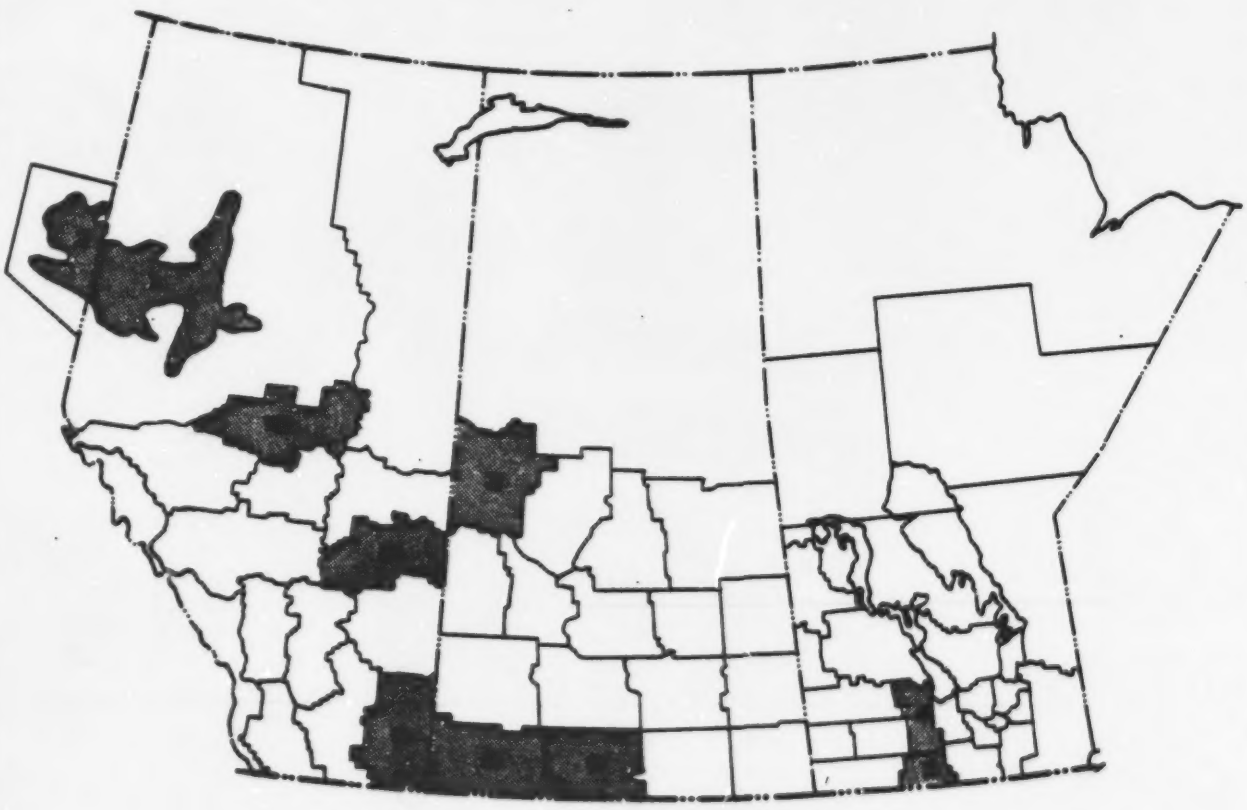

Figure 4.1 Location of census divisions most affected by erosion, ranked by annual cost per improved acre.

In this context the direct net present cost of erosion over the next 25 years, without ameliorative measures and assuming a 10% discount rate is appropriate, is expected to be very high indeed: ($ current)

Alberta	$2.0 billion
Saskatchewan	2.0 billion
Manitoba	0.5 billion
Total	$4.5 billion

If the appropriate social discount rate is, in fact, only 5%/year, then this total would climb to almost $7 billion. In terms of net farm income on the Prairies, this would be approximately equivalent to having a complete crop failure on the Prairies once every five years. Or, similarly, this would have approximately the same anticipated impact as a 20% across-the-board decline in grain prices, i.e. $3.80 bus. for wheat; $2.00 bus. for barley, and $6.35 canola. If this actually happened, the impact would be considered "devastating" (as, indeed, it would be) and it would automatically trigger payments from the Grain Stabilization Fund.* The costs of soil erosion to Prairie agriculture and the Canadian economy in general are much more obscure -- and much more insidious.

In addition, and again according to these same estimates, the annual incremental cost of soil erosion on the Prairies is approximately $3.75 million/year. Thus, annual expenditures of at least this amount are warrented simply to stop further soil erosion on the Prairies.

This is over and above the relatively large public expenditures which are very likely warranted to at least partially rehabilitate already eroded soils on the Prairies (See Section 4.6 following).

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* Two-thirds of which is contributed by the federal government, less the accumulated interest on farmer contributions.

Earlier calculations by the Senate Standing Committee on Agriculture (June 1984, p. 111) provided aggregate estimates which are of the same order-of magnitude:

Total Annual Cost	$368 M/yr.	($5/acre)
Annual Incremental Cost	$5.7 M/yr.	

On the other hand, prior PFRA estimates (11/82, p. 107) were only about 1/10 as large as the imputed losses calculated herein. These differences can generally be traced to various physical assumptions employed in the respective studies; the economic parameters utilized in both studies are almost identical.

4.6 The Economics of Amelioration

The control and/or reclamation of eroded soils (via wind and water) is complex (multi-dimensional) and unique to each and every farm on the Prairies. Usually a "package" of conservation practices is required.

The principal thrust of on-going soil conservation efforts on the Prairies, however, focuses on two opportunities: (1) reduced tillage, and (2) longer rotations with less summerfallow and more forages. The economics of this first possibility is considered immediately following; the second is discussed with respect to maintaining organic matter levels in Section 6.6.

Zero tillage refers to seeding a crop into untilled stubble creating the minimum amount of soil disturbance. Chemical weed control is an important part of the system. Other names are no-till, chemical tillage, direct seeding, eco-fallow, direct drilling and lo-till. In conventional tillage, 100 percent of the topsoil is inverted ty tillage operations. Seeding is done into a prepared seed bed with no surface trash. Conservation or minimum tillage refers to a system with the minimum soil manipulation necessary for crop production under existing soil and climatic conditions. This usually refers to a tillage system requiring fewer tillage operations than in the conventional system. The system also relates to the type of tillage tools used to bury minimal amounts of surface trash, e.g. using blade cultivators.

The principal advantages of a zero or minimum tillage system are the following: (1) reduced wind and water erosion, and (2) labor and equipment operating cost savings. Major potential disincentives include: (1) difficulties with weed control, (2) trash management, (3) higher fertilizer requirements, and (4) additional equipment requirements. But what about the on-farm economics of a zero or minimum tillage option?

In this regard, the research conducted to date on a very limited number of test plots and a very limited number of synthetic farm budgets (for only 3 - 4 yrs.) is far from conclusive:

Zentner and Lindwall, CJPS, July 1982
Zentner and Lindwall, CFE, 1978
Lindwall et al., 21st Alberta Soil Science Workshop, 1984
Malhi, et al., op. cit.
Toly, op. cit.

The results of one such study are illustrative: (Lindwall et al., 1984, p.134).

Table 4.11
AVERAGE PRODUCTION COSTS AND NET RETURNS ($/ha)
FOR DIFFERENT TILLAGE SYSTEMS, SOUTHERN ALBERTA, 1979-83

	Fallow		Recropped	
	Till	No-Till	Till	No-Till
Weed control	72	171	49	68
Variable costs (including weed control)	193	282	219	238
Net returns	131	67	147	129

These estimates suggest that the net farm financial return with zero tillage is lower than with conventional tillage, even in the Brown Soil Zone where the need for moisture conservation (from no-till) and lower weed populations would most likely favor zero or minimum tillage.*

Indeed, the composite research findings of various researchers (in Alberta, at least) consistently suggest that zero (or minimum) tillage may actually result in lower yields, at least in the short-run (4 - 5 years), and higher out-of-pocket farm operating costs, irrespective of their north-south location: (authors interpolation).

	Yields	Costs
Conventional Tillage	100%	100%
Minimum Tillage	95%	105%
Zero Tillage	90%	110%

If this is, in fact, the case then these very approximate indices might translate into B/C ratios of the following relative magnitude:

Conventional	1.0
Minimum Till	0.9
Zero Till	0.8

But, in addition, because various costs are really "shadow prices" in these calculations, the actual out-of-pocket cost changes anticipated with the adoption of minimum or no-till practices could still be underestimated, e.g. increasing real chemical costs vs. decreasing the opportunity cost of labor or sunk machinery costs. A risk factor should also be incorporated into the analysis. This would simply cast more doubt on the economic feasibility of the no-till or minimum till options for the Prairies at this point in time.

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* Although this data may still be imprecise. For example, are variable costs (excluding weed control costs), with stubble, really the same under both the till and no-till options? One would intuitively expect that these costs would be lower under the no-till option (J. Atcheson, 17/10/84).

But in a more qualitative context, it is our professional judgment that this assessment is probably too pessimistic. There are, in fact, numerous social-economic-technological and institutional changes already taking place on the Prairies which will, no doubt, serve to encourage still more adjustments to prevailing soil management practices:

1. The availability and cost of herbicides (esp. for perennial weed control)
2. The availability and cost of alternative tillage and seeding equipment
3. Farm management characteristics
4. Product price changes
5. Genetic improvements
6. More cropping options, and
7. More marketing opportunities.

Farmers and researchers alike are particularly optimistic about (5), (6), and (7). For example, new semi-dwarf barley varieties promise 120-125 bushels per acre with 200 bushel/acre yields "on the horizon". (Barley Booster, fall 1984). New winter wheats are also becoming popular: In Saskatchewan, in the wake of recent successes it is reported that the fall seeding of winter wheat is spreading "like wildfire" (J. Atcheson, 10/84). The yields being obtained from the new semi-dwarf (esp. HY320) 3-M wheats are equally encouraging. These medium quality wheats (with good market opportunities) are yet another innovation which may help to improve the farmers' profit picture in the very near future.

In addition, the elimination of the Crow freight rate is expected to encourage greater crop diversification because it should, ceteris paribus, encourage the development of a stronger livestock industry in the West. The possible removal of the export "cap" on prevailing freight rates could stimulate even more crop production on the Prairies.

Virtually all of these very real on-going developments encourage longer crop rotations and fewer tillage operations. And in this context, a modified technological input "package" is being adopted (albeit still slowly) which

almost inadvertantly serves to help control not one but two or three of the prevailing soil degradation problems on the existing land base on the Prairies, particularly increasing erosion, organic matter loss, and salinity. (Conversely, this trend will likely make the soil acidity problem more acute, unless the increasing use of chemical fertilizers is somehow curtailed, e.g. more forages and livestock production.)

4.7 Research/Policy Implications

There is ample evidence that soil and water erosion is slowly impairing land productivity on the Prairies. Moreover, it is clear that the costs and consequences of soil erosion are not limited to agricultural production. Some of the eroded sediment, along with agricultural chemicals, are transported to water courses. Excessive sediment, nutrient, and chemical loads are detrimental to both human and wildlife activities, and add substantially to the public costs of maintaining water quality.

But there are two underlying problems which thwart the full mobilization of private (on-farm) and public resources to counter this on-going resource degradation on the Prairies.

With respect to the farm sector, the "bottom line" is profits. Over the short-term, many recommended soil conservation practices may result in only marginal profits or even reduced profits. In the short-term, there is no big payoff. Our cursory examination of the short-term payoff to zero or minimum tillage (which appears marginal, at best) is illustrative. (And we have also seen this in other Sections of this report.) Most researchers believe that the adoption of many conservation practices which would sustain the productivity of the land resource* indefinitely simply would not be of economic benefit to the

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* Sustained productivity refers to a state of agricultural production in which the supply of required inputs can be maintained indefinitely at their current levels and the depletion of renewable resources is not progressing at a faster rate than the rate of renewal.

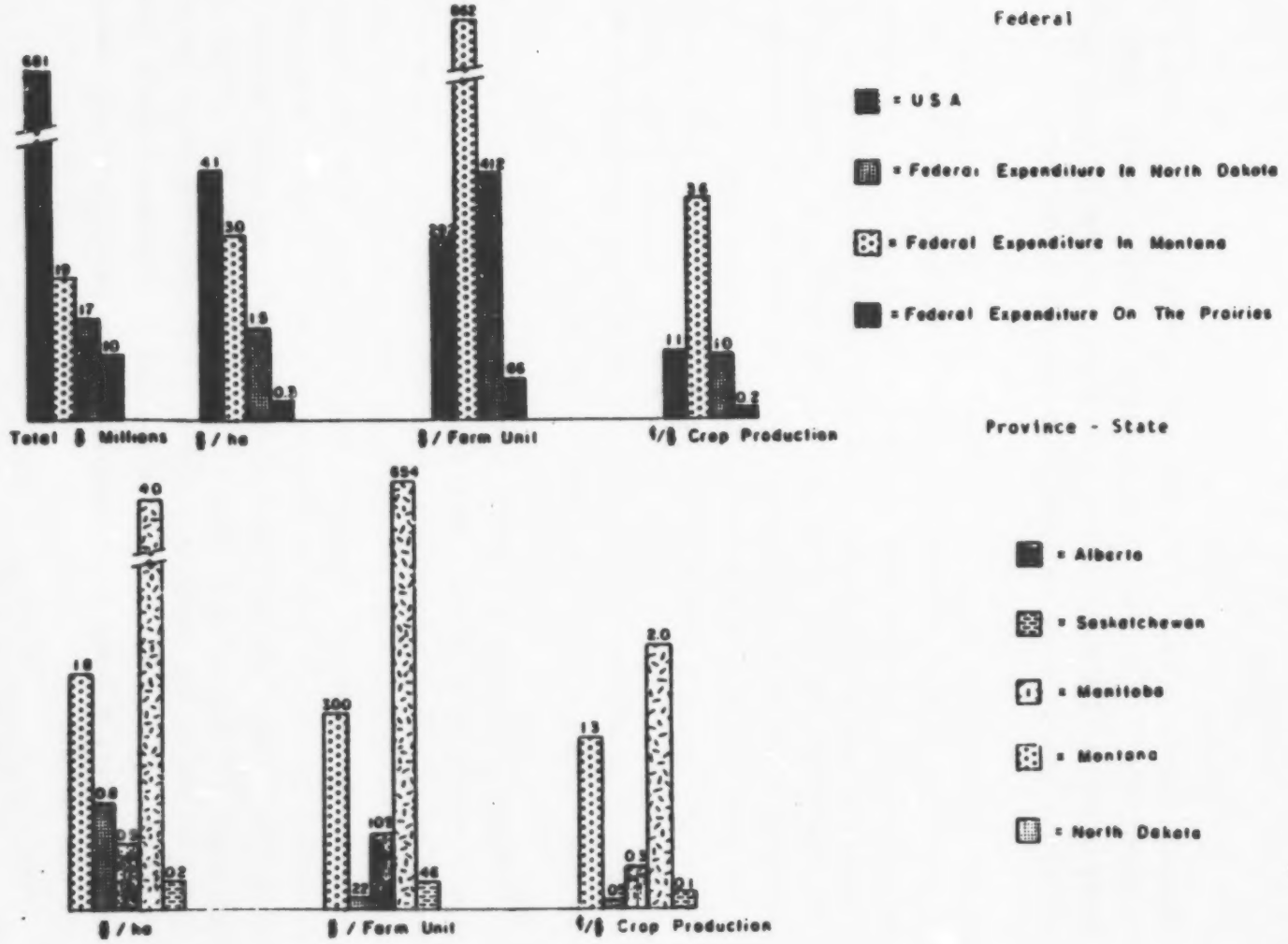
individual farmer unless his planning horizon extended to fifty years or more (Crosson, 1982). On his own, then, there is a strong inherent tendency for a farmer to do too little too late -- however well informed he might be. This is only exacerbated if there are negative externalities involved.

On the other hand, there are numerous social-economic-technological and institutional changes which are already taking place which may really help improve the farm profit picture, at least in the longer run. This would result in a more favorable benefit-cost ratio with respect to various soil conservation practices; the more widespread acceptance of the recommended cultural practices. This would be particularly true if modified input "packages" could be designed (on a region-specific basis) which were effective in the simultaneous control of more than one soil degradation problem (erosion, O.M. loss and salinity). It bears repeating that this scenario (i.e. multi-factor adjustments to generate multiple benefits) is not explicitly considered in the economic analysis conducted anywhere in this report.

With respect to the public sector, perhaps the most dangerous aspect of soil erosion is that it affects our social well-being in an almost insidious manner. Annual reductions in productivity are usually small, and thus, the effects of erosion often go undetected. Furthermore, the impact of erosion on crop yields has often been temporarily masked by increasing the use of fertilizer and other production inputs. In this context, the problem is a lack of public awareness as to how serious the problem really is. Soil and water erosion is not perceived as being a high priority problem because the consequences of benign neglect do not immediately lead to any catastrophic social consequences. In effect, all society is doing is reducing its long-term growth prospects, both quantitatively and qualitatively. Future generations will however, pay for this neglect.

To date, this has been clearly reflected in the size of our financial commitment to soil conservation, as illustrated in accompanying Figure 4.1.

Figure 4.2. Comparative Federal, Provincial and State Expenditures on Soil and Water Conservation 1979.



Source: DRIE/PFRA, Land Degradation and Soil Conservation Issues, Regina, Nov. 1982, pp. 18-19.

In summary, it is our professional judgement that the principal policy implications of this assessment are as follows:

1. More basic research is urgently required, particularly in erosion-prone areas, regarding
   - extent and location of historic and current soil losses
   - economic importance
   - risk associated with management practices
   - rate of change

2. More basic research (on-farm, by region) is also urgently required regarding the private and public payoff to the various conservation measures proposed.

3. But perhaps equally important is the need for more public awareness of the magnitude of the problem. The popular news media must be used extensively, e.g. Soil at Risk (June, 1984). This involves much more than improving our existing agricultural extension services, and

4. With regard to (3), a whollistic interpretation of (1) and (2) is a pre-requisite. And in this context, this research is only a modest beginning.

We would also stress, however, that even more emphasis should immediately be given to the on-going development of region-specific farm input "packages" to encourage longer, more diversified crop rotations to try to simultaneously control more than one soil degradation problem. In this context, the economics of these regional input packages should also be examined in a more comprehensive and contemporary framework, all of which can be done in conjunction with the basic research requirements identified above.

5.0 SOIL ACIDIFICATION

5.1 Overview

Most of the acid soils that are farmed on the prairies were acid before farming due to the natural soil processes of leaching and microbial action. The addition of acid-forming materials to the soils can, however, make acid soils more acid, or can lower the pH of near-acid soils into the acid range. The inputs of major concern for causing acidification of soils are nitrogen (N) and sulfur (S) fertilizers; and, of lesser concern in western Canada, airborne S and N pollutants. Low soil pH reduces nutrient availability and can allow aluminum and manganese to become toxic to crops (Nyborg and Hoyt, 1978; Penney et al., 1977).

The distribution of soils that are presently acid correlates to the distribution of Luvisolic (Gray Wooded) and Solonetzic soils in a general sense. The acid soil problem has been recognized in the Peace River region for approximately 20 years and in the Scott area of Saskatchewan for about the same amount of time. In the past 10 years a much wider distribution of acid soils has been recognized. This wider distribution is due mainly to greater awareness by soil scientists and recent inventories but also to lowering of soil pH by heavy use of N fertilizers. It is not possible to estimate, with a reasonable level of confidence, how much man-aggravated acidification has occurred as baseline data and monitoring programs have not been conducted. We have taken the approach in this report of estimating the current extent of acid soils (soils with topsoil pH less than 6). Then, by considering soil sensitivity and management practices and trends, we have predicted the amount of acidification that will occur in 25 years. This will occur as an increase in severity of soils that are presently acid, and due to lowering of the pH of near-acid soils.

5.2 Estimation of Risk, Extent and Severity

Acid soil maps, at general scales, have been prepared for the prairies and sensitivity to acidification mapping is currently in progress - a response to concerns about acid rain. Monitoring of pH of soil samples submitted to provincial soil testing labs has been conducted for several years in Alberta and Saskatchewan. A provincial survey of soil pH was recently conducted in Saskatchewan (Rostad et al., 1983). The extent of acid soils can be estimated with reasonable confidence (much higher than for salinized or eroded soils), but the amount of man-induced acidification is not known. We have also estimated the amount of increase in acid soils over the next 25 years, which will be primarily due to the acidifying effect of agricultural practices (See Appendix A). The amount of increase in extent and severity of acid soils provides an estimate of the magnitude of man-induced acidification.

5.3 Summary of Acid Soil Estimates

5.3.1 Acid Soils in Western Canada

The areas where acid soils and continuing acidification are of greatest extent are the Peace River region, north-central and east-central Alberta, and north-western Saskatchewan. There are a total of six million acres of acid soils in the grain growing region (Table 5.1), and this is estimated to be increasing by 175,000 acres per year. Broken down by province the annual increase in extent of acid soils due primarily to agricultural practices is:

Alberta + B.C. Peace	100,000	acres
Saskatchewan	70,000	acres
Manitoba	5,000	acres
Total	175,000	acres

In addition to an increase in extent of acid soils the soils are also becoming more severely acid. The extent of acid soils is predicted to be 10.6 million acres by the year 2008.

Table 5.1
SUMMARY OF CURRENT AND PROJECTED EXTENT AND SEVERITY OF ACID SOILS IN WESTERN CANADA
(millions of acres)

	Year 1984			Year 2008		
Province	Mod. Acid (pH 5.5-6)	Strongly Acid (pH 5-5.5)	Total Acid	Mod. Acid (pH 5.5-6)	Strongly Acid (pH 5-5.5)	Total Acid
Alta. & B.C. Peace	3.46	.717	4.18	3.40	3.45	6.85
Saskatchewan	1.80	0	1.80	1.80	1.80	3.80
Manitoba	0	0	0	.132	0	.132
TOTALS	5.26	.717	5.98	5.33	5.25	10.6

5.3.2 Acid Soils in Alberta and the B.C. Peace

Acid soils have been identified and researched in the Peace River area and in east-central Alberta for approximately 20 years (Cairns, 1971; Hoyt, 1982, 1979; Hoyt et al., 1981, 1974; McCoy and Webster, 1977; Nyborg and Hoyt, 1978; and Penney et al., 1977). The acid soils are typically the Luvisolic (Gray Wooded) and Solonetzic soils, although some Chernozemic soils (typically less than 5%, Penney et al., 1977) in all soil zones are acid.

The distribution of acid soils and soils most likely to become acidified corresponds to the distribution of Solonetzic and Luvisolic soils (Acid Soils Map - rear pocket). The estimated extent of soils that are currently acid is approximately 4.2 million acres which is 13 percent of the Improved land base (Table 5.2). The areas with the greatest concentrations of acid soils are the Peace River area (33% of C.D.'s 15 and 55), and east-central Alberta (25.8% of C.D. 7; 21.7% of C.D. 10). Approximately 10 to 15 percent of the Luvisolic

Table 5.2
EXTENT AND SEVERITY OF ACID SOILS IN ALBERTA AND THE B.C. PEACE
SUMMARIZED BY CENSUS DIVISION (Improved Land only in millions of acres)

Census Division	Year 1984					Year 2008		
	Mod. Acid pH 5.5-6.0		Strongly Acid 5.0-5.5		Total % Acid	Mod. Acid pH 5.5-6.0	Strongly Acid 5.0-5.5	Total % Acid
	%	M. Acres	%	M.Acres		M. Acres	M. Acres	
1	0.8	.013	0	0	0.8	.013	0	0.8
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	13.8	.268	2.4	.046	16	.268	.268	28
5	0	0	0	0	0	0	0	0
6	1.9	.037	0	0	1.9	.037	.037	3.8
7	20.7	.618	5.1	.152	26	.618	.618	41
8	4.4	.091	0	0	4.4	.091	.091	8.8
9	0	0	0	0	0	0	0	0
10	17.4	.624	4.3	.154	22	.624	.624	35
11	4.3	.089	0	0	4.3	.089	.089	8.6
12	12.6	.148	3.1	.038	16	.148	.148	25
13	7.8	.153	2.0	.039	9.8	.153	.153	16
14	8.0	.018	2.0	.004	10	.018	.018	16
15	27.0	1.15	6.0	.256	33	1.15	1.15	54
55 (B.C.)	27.0	.250	6.0	.060	33	.250	.250	54
TOTALS		3.46		.717		3.40	3.45	
		4.18 (13.1%)				6.85 (21.5%)		

soils in C.D.'s 12, 13 and 14 are presently acid. These estimates of extent are very similar to those made by Penney et al. (1977). They also estimated that 24 percent of the cultivated land in Alberta, excluding the Peace River region; and 34 percent of the cultivated land in the B.C.-Alberta Peace River region is in the near-acid range (pH 6.1 to 6.5) and is at risk of acidification. This acidification will be mainly caused by farming inputs. There are also examples throughout the province where soils with low risk have become acidified by very heavy applications of nitrogen fertilizers. The risk assessment is based on normal cropping procedures.

We have estimated the extent of acid soils over the next 25 years will increase from 4.2 to 6.8 million acres; a mean annual increase of 100,000 acres. In addition to an increase in extent (number of acres) the severity of acidity will also increase, with the very strongly acid (pH less than 5.5) soils increasing from 20 to 50 percent of acid soils. This will have very considerable costs in terms of reduced yields, and will limit the range of crops that can be grown.

5.3.3 Acid Soils in Saskatchewan

The extent and severity of acid soils in Saskatchewan has been interpreted from the map prepared by Rostad et al. (1983). The distribution of acid soils is not simply correlated to Solonetzic and Luvisolic soils; as Chernozemic soils in the Unity-Scott area, the Meadow Lake area, and the Kerrobert area are among the most acid in the province. The soils of western Saskatchewan generally have lower pH than those east of the third meridian due to the higher lime content in the eastern soils.

We have estimated the total extent of acid soils in the province to be 1.8 million acres, which is approximately 3.7 percent of the improved land base (Table 5.3). The low provincial percentage is misleading however, as some areas have very high proportions of acid soils. The northwestern agricultural area is the most severely affected, with 35 and 25 percent of the improved lands in C.D.'s 17 and 18 respectively being acid. C.D. 13 in western Saskatchewan also has a high percentage (13.2%) which is concentrated in fairly small areas. The Solonetzic soils in the Weyburn-Estevan area in southeastern Saskatchewan also have high proportions of acid soils (10% of C.D. 2).

The acid soils in Saskatchewan do not appear to be as strongly acid as many of those in Alberta, with essentially all soils falling into the pH 5.5 to 6.0 range (Table 5.3). Further acidification due mainly to agricultural inputs will increase the acres of soils with pH less than 6 and will lower the pH of those soils that are currently acid. We have estimated the extent of acid soils will increase from 1.8 million acres to 3.6 million in 25 years, representing an annual increment of 70,000 acres. The most severely affected areas would have 50 to 70 percent of improved land acidified. Interpretation of data from Rostad et al. (1983) indicates there are approximately 16 million acres in the near-acid pH range (pH 6.1-6.5) which would be sensitive to acidification. Perhaps of more significance, the severity of acidity would increase, with the percentage of very strongly acid soils (pH less than 5.5) increasing from zero to 50 percent of soils that are acid. This would have very serious effects on yields and would severely limit the selection of crops that could be grown.

Table 5.3
EXTENT AND SEVERITY OF ACID SOILS IN SASKATCHEWAN SUMMARIZED
BY CENSUS DIVISION (Improved Land only in millions of acres)

Census Division	Year 1984					Year 2008		
	Mod. Acid pH 5.5-6.0		Strongly Acid 5.0-5.5		Total % Acid	Mod. Acid pH 5.5-6.0	Strongly Acid 5.0-5.5	Total % Acid
	%	M. Acres	%	M.Acres		M. Acres	M. Acres	
1	5.7	.152	0	0	5.7	.152	.152	11
2	10	.302	0	0	10	.302	.302	20
3	0	0	0	0	0	0	0	0
4	6.9	.158	0	0	6.9	.158	.158	14
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0.4	.010	0	0	0.4	.010	.010	0.8
13	13	.425	0	0	13	.425	.425	26
14	0	0	0	0	0	0	0	0
15	2.0	.064	0	0	2.0	.064	.064	4
16	1.3	.029	0	0	1.3	.029	.029	2.6
17	35	.661	0	0	35	.661	.661	70
18	25	.004	0	0	25	.004	.004	50
PROVINCE		1.80		0		1.80	1.80	
		1.80 (3.7%)				3.61 (7.4%)		

5.3.4 Acid Soils in Manitoba

There are no significant acreages of acid soils in Manitoba at present, and the soils generally have high buffering capacity. There are however, approximately 1.2 million acres that are sensitive to acidification and, of these, we estimate approximately 0.13 million acres will be in the acid range within 25 years. This is an average annual increase of 5000 acres over the province. These acres will however, be confined to fairly small areas, with the Neepawa-Brandon area in C.D. 7 being most affected (Table 5.4 and Acid Soils Map - rear pocket). Census Divisions 3, 4, 8, 9 and 17 also contain soils that are sensitive and may become acid.

Table 5.4
EXTENT AND SEVERITY OF ACID SOILS IN MANITOBA
SUMMARIZED BY CENSUS DIVISION

Census Division	Year 1984		Year 2008	
	Moderately Acid (pH 5.5-6.0)			
	%*	M. acres	%*	M. acres
1	0	0	---	---
2	-	-	---	---
3	0	0	0.4	.005
4	0	0	0.5	.005
5	-	-	---	---
6	-	-	---	---
7	0	0	9.3	.083
8	0	0	0.2	.023
9	0	0	1.7	.009
10	-	-	---	---
11	-	-	---	---
12	-	-	---	---
13	-	-	---	---
14	-	-	---	---
15	0	0	---	---
16	-	-	---	---
17	0	0	0.6	.007
18	-	-	---	---
19	-	-	---	---
20-23	-	-	---	---
PROVINCE		0		.132 (1%)

* Percent of Improved Land

5.4 Effects of Acidity on Yields

The effect of acidity on yields has been estimated by comparing pH levels to expected yields of wheat, barley and canola (Table 5.5). These estimates were derived from several research reports and researchers opinions (Alta. Ag. Land Base Study, July 1984; Hoyt, 1982; D. Penney, Alta. Ag., pers. comm. July, 1984; Penney et al., 1977; Ukrainetz, 1984, 1982, 1981, 1979, 1969). Canola appears to be affected less by low pH in the Peace River region than in east-central Alberta, which seems to correlate to amounts of soluble aluminum and manganese (D. Penney, pers. comm., July 1984). Yields can be returned to normal by liming, but it may take three to five years after liming to realize increases on some soils (H. Rostad, Sask. Inst. Pedology, pers. comm., 1984).

Table 5.5
EFFECTS OF ACIDITY ON YIELDS

	pH Range (in H_2O)		
Crop	5.1-5.5	5.6-6.0	> 6.0
	----- Relative Productivity (%) -----		
In Manitoba, Saskatchewan, Central Alberta:			
Wheat	85	95	100
Barley	75	90	100
Canola	75	90	100
In Peace River Region:			
Wheat	85	95	100
Barley	75	90	100
Canola	85	95	100

Data Sources:
1. H. Ukrainetz, 1969, 1979, 1981, 1982, 1984. Agriculture Canada.
2. P. Hoyt, 1982.
3. D. Penney et al. 1977.
4. D. Penney, personal communication July, 1984.

5.5 Economic Costs

The methodology utilized to calculate what acid soils on the Prairies are costing, and will cost, Prairie agriculture in the future, without ameliorative measures, is identical to the procedures employed in Sections 3.5 and 4.5 preceding. (Also see Appendix B). That is:

1. Calculate the weighted yield loss, per C.D.
2. Translate (1) into an equivalent acreage loss
3. Translate (2) into dollar costs (consistent with Appendix B)

The resulting tabulations are provided in Table 5.6 following.

Table 5.6 can then be interpreted in terms of an annual cost per improved acre and an annual cost per farm. These calculations are provided in accompanying Tables 5.7 - 5.9 which very clearly identify, geographically, where acid soils are a particularly serious (and growing) economic problem, namely ENE Alberta, NW Saskatchewan, and the Alberta-B.C. Peace region (Figure 5.1).

Annual per farm costs in ENE Alberta and NW Saskatchewan presently amount to about $2,000/farm/year. In the Peace region, these costs already average in excess of $1,000/farm/year. Perhaps even more alarming are the projected costs in 25 years when, in these same regions, the annual per farm cost (in $ 1984) is expected to at least double and, in some cases, even triple.

For the Prairies as a whole, it is estimated that acid soils presently reduce crop revenues by about 0.5 percent -- but that this will probably reach 1.5 percent during the next 25 years, given the current structure of agriculture (Table 5.10). This is approximately equivalent to a current net farm income loss of, say, 2%; climbing to perhaps 4 - 5% of net farm income in a couple of decades. But even these Prairie-wide estimates tend to obscure the severity of various potential regional impacts.

Accordingly, the anticipated cumulative cost over 25 years, assuming a 10%

Table 5.6
ACIDITY - ACTUAL & PROJECTED ANNUAL COST WITHOUT AMELIORATIVE MEASURES, PRAIRIE PROVINCES, BY CENSUS DIVISION, 1984-2008 ($,000)

Census Division	Alberta			Saskatchewan			Manitoba		
	1984	1990	2008	1984	1990	2008	1984	1990	2008
1	54	94	214	674	1159	2612	--	--	--
2	--	--	--	1337	2333	5322	--	--	--
3	--	--	--	--	--	--	0	13	50
4	1357	1905	3548	628	1090	2477	0	13	51
5	--	--	--	--	--	--	--	--	--
6	375	616	1339	--	--	--	--	--	--
7	8520	11131	18965	--	--	--	0	192	767
8	904	1473	3182	--	--	--	0	58	233
9	--	--	--	--	--	--	0	23	92
10	9179	11940	20223	--	--	--	--	--	--
11	826	1353	2932	--	--	--	--	--	--
12	1895	2458	4147	55	95	214	--	--	--
13	2044	2628	4378	2465	4203	9417	--	--	--
14	182	235	396	--	--	--	--	--	--
15	10061	13343	23191	474	794	1755	--	--	--
16	--	--	--	205	344	760	--	--	--
17	--	--	--	5343	8952	19778	0	13	52
18	--	--	--	25	41	90	--	--	--
19	--	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--
55 (B.C.)	2799	3658	6233						
TOTAL	38196	50834	88748	11206	19011	42425	0	312	1245

Table 5.7
ACIDITY - PROJECTED FARM IMPACTS IN ALBERTA AND THE B.C. PEACE AREA WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division	Annual Cost/ Improved Acres ($ Current)			Annual Cost/Farm* ($ Current)			Rank**			
							Provincial		Prairies	
	1984	1990	2008	1984	2000	2008	1984	2008	1984	2008
1	.03	.06	.13	30	52	118	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--
4	.70	.98	1.83	855	1200	2234	8	7	--	10
5	--	--	--	--	--	--	--	--	--	--
6	.19	.31	.68	87	143	311	--	--	--	--
7	2.85	3.73	6.35	2208	2885	4916	1	1	1	2
8	.44	.71	1.53	161	263	568	9	9	--	--
9	--	--	--	--	--	--	--	--	--	--
10	2.56	3.33	5.63	1288	1676	2839	3	3	4	4
11	.40	.65	1.40	118	193	418	10	10	--	--
12	1.61	2.09	3.53	604	783	1322	5	5	6	7
13	1.04	1.34	2.23	376	483	804	6	6	8	9
14	.83	1.07	1.81	222	287	484	7	8	9	--
15	2.36	3.13	5.43	1221	1619	2814	4	4	3	3
55 (B.C.)	3.00	3.92	6.69	1496	1955	3331	2	2	3	3
PROVINCE	1.14	1.52	2.67	610	813	1421				

* Based on farm numbers in 1981, consistent with the 1981 Census of Agriculture.

** Ranked according to the annual cost/improved acre where 1 = worst.

Table 5.8
ACIDITY - PROJECTED FARM IMPACTS IN SASKATCHEWAN WITHOUT WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division	Annual Cost/ Improved Acre ($ Current)			Annual Cost/Farm* ($ Current)			Rank**			
							Provincial		Prairies	
	1984	1990	2008	1984	1990	2008	1984	2008	1984	2008
1	.25	.44	.98	194	333	751	6	6	--	--
2	.44	.77	1.76	376	656	1495	4	4	--	--
3	--	--	--	--	--	--	--	--	--	--
4	.27	.48	1.08	288	499	1134	5	5	--	--
5	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--
12	.02	.04	.08	18	32	71	9	9	--	--
13	.76	1.30	2.92	718	1225	2744	3	3	9	7
14	--	--	--	--	--	--	--	--	--	--
15	.15	.25	.54	80	133	295	7	7	--	--
16	.09	.15	.34	55	92	204	8	8	--	--
17	2.83	4.74	10.47	1824	3055	6750	1	1	2	1
18	1.41	2.32	5.08	806	1323	2903	2	2	6	5
PROVINCE	.23	.39	.87	166	282	630				

* Based on farm numbers in 1981, consistent with the 1981 Census of Agriculture.

** Ranked according to the annual cost/improved acre where 1 = worst.

Table 5.9
ACIDITY - PROJECTED FARM IMPACTS IN MANITOBA WITHOUT
WITHOUT AMELIORATIVE MEASURES, SELECTED YEARS, BY CENSUS DIVISION

Census Division*	Annual Cost/ Improved Acre ($ Current)			Annual Cost/Farm** ($ Current)			Rank***			
							Provincial		Prairies	
	1984	1990	2008	1984	1990	2008	1984	2008	1984	2008
3	0	.01	.04	0	5	19	6	6	--	--
4	0	.02	.06	0	8	32	4	4	--	--
7	0	.21	.86	0	120	481	1	1	--	--
8	0	.06	.25	0	35	141	2	2	--	--
9	0	.04	.17	0	23	91	3	3	--	--
17	0	.01	.05	0	5	19	5	5	--	--
PROVINCE	0	.02	.09	0	11	42	-	-	--	--

* Only includes C.D.'s with non-zero values.
** Based on farm numbers in 1981, consistent with the 1981 Census of Agriculture.
*** Ranked according to the annual cost/improved acre where 1 = worst.

Table 5.10
ACIDITY - TOTAL PROJECTED COSTS WITHOUT AMELIORATIVE MEASURES, PRAIRIE PROVINCES*
($ Millions Current)

Year	Alberta**	Saskatchewan	Manitoba	TOTAL PRAIRIES
1984	38.2 (1.2%)	11.2 (0.3%)	0.0 (0.0%)	49.4 (0.5%)
85	40.3	12.5	0.1	52.9
86	42.4	13.8	0.1	56.3
87	44.5	15.1	0.2	59.8
88	46.6	16.4	0.2	63.2
89	48.7	17.7	0.3	66.7
1990	50.8 (17%)	19.0 (0.4%)	0.3 (-)	70.1 (0.8%)
91	52.9	20.3	0.4	73.6
92	55.0	21.6	0.4	77.0
93	57.2	22.9	0.5	80.6
94	59.3	24.2	0.5	84.0
95	61.4	25.5	0.6	87.5
96	63.5	26.8	0.6	90.9
97	65.6	28.1	0.7	94.4
98	67.7	29.4	0.7	97.8
99	69.8	30.7	0.8	101.3
2000	71.9 (2.3%)	32.0 (0.7%)	0.8 (-)	104.7 (1.2%)
01	74.0	33.3	0.9	108.2
02	76.1	34.6	0.9	111.6
03	78.2	35.9	1.0	115.1
04	80.3	37.2	1.0	118.5
05	82.4	38.5	1.1	122.0
06	84.5	39.8	1.1	125.4
07	86.6	41.1	1.2	128.9
08	88.7 (2.9%)	42.4 (1.0%)	1.2 (-)	132.3 (1.5%)
Direct Net Present Cost***	5% 759	295	6	1060
	10% 489	190	5	683
	15% 348	135	3	486
Total Net Present Cost****	5% 1214	472	10	1696
	10% 782	304	6	1092
	15% 557	216	5	778

* Percent of crop revenue indicated in brackets.
** Includes the Peace area of British Columbia.
*** Discount rate = 5%, 10% and 15%.
**** Direct plus indirect where the GDP multiplier = 1.6 (UMA, 1983).

ACID SOILS

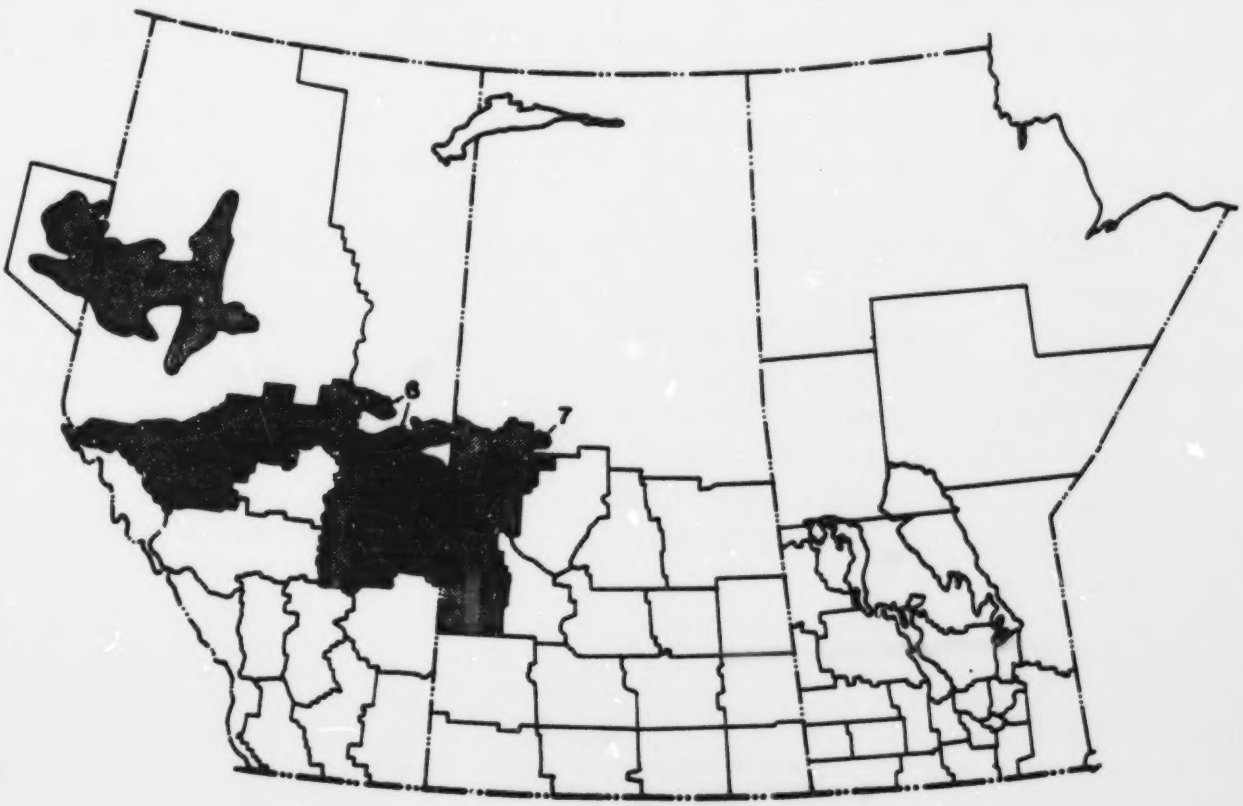


Figure 5.1 Location of census divisions most affected by acid soils, ranked by annual cost per improved acre.

annual discount rate is appropriate, is expected to reach almost $700 million in $ 1984, distributed between the respective provinces as follows:

Alberta (incl. B.C. Peace region)	$489 M	(71%)
Saskatchewan	190	(28%)
Manitoba	4	(1%)
Total	$683 M	

If, in fact, a social discount rate of only 5% per annum is appropriate, this cumulative Prairie-wide cost of soil acidification could exceed $1 B over the next 25 years. Considering the indirect costs as well further inflates the respective estimates (Table 5.10).

Finally, with respect to the projected <u>increases</u> in soil acidification during the next 25 years, we have calculated that the <u>incremental</u> <u>annual</u> cost amounts to approximately 3.5 M per annum. This is indicative of the upper limit on expenditure levels which could be justified to arrest further acidification of Prairie soils (Table 5.11). Expenditures of this magnitude would be over-and-above any expenditures for the rehabilitation of existing acid soils.

Table 5.11
MAXIMUM ANNUAL EXPENDITURE SUGGESTED TO
ARREST FURTHER ACIDIFICATION OF PRAIRIE SOILS

Province	$ Current
Alberta	$2,106,000
Saskatchewan	1,300,000
Manitoba	50,000
TOTAL PRAIRIES	$3,456,000

5.6 The Economics of Amelioration

The amelioration of acid soils is relatively straight-forward; these soils simply require the periodic application of lime to raise the pH. Depending upon initial pH levels, climate, soil characteristics, chemical fertilizer application rates, and the type of crop grown, this should be done every ten to fifteen years.

Given current farm product prices, the on-farm economics of liming largely depends upon the on-farm cost of lime. This is illustrated in accompanying Tables 5.13 - 5.14. At $35/tonne, with current forage and grain prices, liming highly acid soils is generally a financially feasible proposition. These calculations illustrate that at interest rates of 10%/annum (as assumed in Tables 5.13 - 5.14) the payback period is, in fact, only about two years (some soils may have a lag time of three to 5 years for response - H. Rostad, pers. comm.)

Another more recent study (Alberta Agriculture, August 1984) is equally optimistic about the economic return from liming acid soils, assuming, once again, that the on-farm price of lime is only $35/tonne. This research indicates a typical B/C ratio in the range 1.24 - 1.92, assuming a 5% discount rate is appropriate. But more importantly, the internal rate of return is calculated to range from 10 - 22% per annum. This means that if the lime was readily available to farmers at $35/tonne, farmers could even borrow money at current commercial interest rates and almost be assured of making a profit.

Again, however, it is very difficult to generalize:

> " ... The return of money invested in liming depends on the size of the yield increase obtained, the values of the crop and the lime, and the interest rate charged for money borrowed. Since most of these will vary from farm to farm and from year to year, it is not possible to present a calculation which will apply to all farm situations." (Alberta Agriculture, August 1982).

Nevertheless, ready access to lime at $35/tonne, delivered, is the key.

Table 5.12 **Average yields of various crops grown on acid soils before and after liming to pH 6.5.**

Crop	Soil Zone	pH	Yields t/ha		
			no lime	lime	increase
wheat	Dark Brown	5.2	1.57	1.82	0.25
canola	Dark Brown, Thin Black	4.9–5.2	1.31	1.55	0.24
	Gray	4.9–5.8	0.89	1.26	0.37
barley	Dark Brown, Thin Black	4.9–5.2	2.40	2.83	0.43
	Gray	4.9–5.8	2.20	2.99	0.79
alfalfa	Dark Brown, Thin Black	4.9–5.2	4.62	5.72	1.10
	Gray	4.5–6.0	2.71	4.78	2.07
red clover	Dark Brown, Thin Black	4.9–5.2	2.90	3.17	0.27
	Gray	4.5–6.0	3.80	4.27	0.47

* tonne per acre = 0.40 t/ha

Table 5.13 **Yield increases and net returns from liming alfalfa grown on soils with various pH values.**

Soil pH	Lime Added		Annual Yield Increase		Years to pay for lime
	t/ha*	$/ha	t/ha*	$/ha	
5.7	2.25	$ 78.75	0.90	$ 54.00	less than 2
5.5	3.35	117.25	1.80	108.00	less than 2
5.3	4.50	157.58	2.45	147.00	less than 2
5.1	5.60	196.00	3.00	180.00	less than 2
4.9	6.70	234.50	3.75	225.00	less than 2

* tonne per acre = 0.40 (tonne/ha): ton per acre = 0.45 (tonne/ha)
Calculations are based on 1 tonne of applied lime costing $35, and 1 tonne of alfalfa hay worth $60.

Table 5.14 **Yield increases and net returns from liming barley grown on soils containing different levels of extractable aluminum.**

Soil Aluminum ppm	Lime Added		Annual Yield Increase		Years to pay for lime
	t/ha*	$/ha	t/ha*	$/ha	
1	1.12	$ 39.20	0.27	$ 31.05	less than 2
2	2.25	78.75	0.43	49.45	less than 2
4	3.35	117.25	0.70	80.50	less than 2
6	4.50	157.50	0.86	98.90	less than 2
8	5.60	196.00	0.97	111.55	less than 2

* tonne per acre = 0.40 (tonne/ha); for barley bu/ac = 18.6 (tonne/ha)
Calculations are based on 1 tonne of applied lime costing $35 and 1 tonne of barley grain worth $115.

Source: Alberta Agriculture. Crop Yields and Economics of Liming Acid Soils. Agdex 534-2, Edmonton, August 1982.

5.7 Research and Policy Implications

The research needs for acid soils are, perhaps, less critical than the research required with respect to some of the other soil degradation problems discussed in this report. Nevertheless, the list is still somewhat intimidating:

1. Thoroughly document the problem:
   - extent and location
   - economic importance
   - rate of change
   - areas potentially susceptible to acidification.
2. Document relationship of farm cultural practices (particularly fertilizer use) to pH levels, by region.
3. Document relationship of liming to pH levels and specific crop yields, by region.
4. Assess the on-farm economics, by region, crop, and pH level, of recommended control practices.

In any event, because the underlying causes of acidification are relatively well-known and because control and/or reclamation measures are equally obvious, public efforts in this regard should already extend well beyond the laboratory. These programs should focus on:

1. Improved diagnostic services.
2. Improved on-farm extension services (technology transfer and public awareness).
3. Assuring lime supplies are adequate in acid-prone regions.
4. On-farm subsidies for product and for transport costs.

Some form of subsidy program is essential, as already implied in Section 5.6 above. Most of these programs are, in fact, already in place. Basically, existing programs should simply be up-graded.

6.0 ORGANIC MATTER LOSS

6.1 Overview

Loss of organic matter (O.M.) from topsoil horizons results in loss of nutrients (especially nitrogen); loss of nutrient supply power; and deterioration of physical properties of the soil that are important for crop growth. Lower O.M. levels correlate with surface crusting, higher bulk density, slower water infiltration, lower available water capacity, and higher erosion risk (McGill et al., 1981; Campbell and Biederbeck, 1980; Newton et al., 1945). Deterioration of these soil quality factors results in lower crop yields.

The correlation of total O.M. concentration to nitrogen supply power and productivity losses is not as simplistic as was thought a few years ago (W. McGill, U. of Alberta, pers. comm.). The balance between active and inactive fractions of the O.M. are more critical than the total amount of O.M. in determining how much crop N and immobilized N are available each year. Soils with fairly low levels of total O.M. may be very active, and soils that are inactive may require several years of additions to regain activity. The important goal in O.M. management (and nutrient management) is to recycle rather than to mine it (McGill et al., 1981; McGill and Hoyt, 1977).

6.2 Estimates of Risk, Extent and Severity of O.M. Loss

Organic matter is lost by erosion and by microbial action, and is diluted by deep plowing. The rate of loss is highest in the initial years of cultivation and then usually decreases dramatically. A recent survey of a large number of farm sites across all soil zones of Alberta by Reinl and McGill (Reinl, 1984) found a negative curvilinear trend for change in concentration of organic matter in topsoils in the Brown soil zone, but that no evidence exists of a continuing decline in the Dark Brown and Black soil zones. It appears that in the past 15 years the trend in O.M. levels in the Dark Brown and Black soils in

Alberta has reversed towards a higher steady-state level, reflecting shifting management practices (Reinl, 1984).

In terms of regional trends the Brown soils had low initial levels of O.M., which were considerably reduced from about 1900 to 1960, but the rate of reduction has slowed or perhaps ceased on the average farm, and is building on some farms. The level is however, still critical on most farms. In the Dark Brown and Black soils initial levels were fairly high and they have been reduced but with a shift to less summerfallow (at least in Alberta and Manitoba) the trend is favorable. Management is the critical variable, and there are still many examples of poor management and declining levels. Gray Luvisol (Gray Wooded) soils have essentially no organic matter in the A horizon (topsoil layer) in their natural state, and generally benefit from cropping by gaining organic matter. The magnitude and direction of change in O.M. is related to the original O.M. content and the type of management. Losses occur if removals exceed additions.

The approach of using nitrogen balance calculations to estimate costs of O.M. loss has been attempted by various researchers (Rennie et al., 1976; Hedlan and Cho, 1974) but it is limited by many unknown factors. Rates of mineralization and denitrification, and N losses by erosion are not known, which severely limits use of a balance sheet approach. As observed by Campbell and Biederbeck (1980):

> " ... some loss of N was inevitable once the soil was broken; however the losses seem to have been expedited by the practice of summerfallowing."

They also concluded there was a decrease in the amount of N lost over time, and after 80 years of cultivation most of the losses had occurred. These observations are consistent with those of Reinl (1984). Continuing losses of N may be primarily due to erosion (Campbell and Biederbeck, 1980).

6.3 Summary of Extent and Severity of O.M. Loss

The extent and severity of organic matter loss is tied strongly to management practices, with considerable differences in trends and rates occurring between farms. For this reason we have not attempted to map O.M. loss and regionalize impacts as was done for the other degradation issues. A few general statements regarding regionalization of the issue can be made:

1. Organic matter levels are probably continuing to decline on most farms in the Brown Soil Zone. This is attributed to wheat-fallow rotation systems.
2. Organic Matter levels in the Dark Brown and Black Soil Zones may be approaching a steady-state level that is higher than levels were 30 years ago on many farms. This is attributed to longer rotations and return of more crop residue to the soil.
3. Gray Luvisol soils gain organic matter when farmed, especially when forage crops are included in rotations.
4. Farm-level management factors account for more variability in O.M. levels than climatic or soil factors.

6.4 Effects of O.M. Loss on Yields

Due to the strong farm-level management control we have not attempted to estimate extent or severity by a mapping procedure, and correlate to yield reductions. An economic evaluation was attempted to determine if input costs which were not being translated into extra yield could be used to indicate severity of O.M. loss and associated problems (Appendix C). This approach is sensitive to all soil degradation issues - not just O.M. loss, therefore costs cannot be isolated as being due to O.M. loss.

Amelioration of O.M. loss involves soil management practices which replace more O.M. than is being removed. This includes additions of O.M. by manuring, straw addition, fertilizing to increase growth, and continuous cropping or minimum tillage. Prevention of erosion is of course also necessary. Farming practices that increase O.M. levels are being carried out by some farmers in all soil

zones, and are being done economically. Reduction of summerfallow frequency is usually identified as the most important step in improving O.M. levels (Rennie et al., 1976; Campbell and Biederbeck, 1980; Campbell and Zentner, 1984).

6.5 Economic Costs

Many of the methodological problems inherent to an economic evaluation of organic matter losses on the Prairies have already been discussed in the preceding. When do Organic Matter losses (and what kind) affect productivity levels (yields) and to what extent? In a purely physical context, this is very difficult to quantify. This study was, therefore, unable to isolate the on-going economic costs of O.M. losses on the Prairies.

At the same time, a general indication of combined annual erosion-O.M. costs on the Prairies, by C.D., is attached as Appendix C. One previous study (PFRA, 1982, pp. 106-107) has also calculated that if the area in summerfallow on the Prairies could be reduced by 5.5 million hectares (13.6 M. acres), this would result in an annual reduction in nutrient loss of approximately $41 million, valued by cost in chemical fertilizer per year. This is based on the assumption that the combined losses of mineralized nitrogen are about 15 percent higher on fallow land than on land under crop.

6.6 The Economics of Amelioration

Maintaining or improving O.M. levels on the Prairies is generally considered in conjunction with various erosion control measures. Two major ameliorative measures which are now receiving considerable attention are: (1) longer rotations with less summerfallow and more forages (green manuring), and (2) reduced tillage operations. The economics of this first possibility are considered immediately following; the second was discussed with respect to erosion control in Section 4.6.

Considerable research has now been conducted regarding the economics of less summerfallow on the Prairies:

MAA/ECA, 1981
Ausenhus, 1977
Campbell and Zentner, 1984
Clark, 1980
Zentner, 1984
Campbell et al., 1983
Robertson, 1983
Carter and Rennie, 1983
Macartney, 1984
Alberta Agriculture, 1984

And virtually all of these studies (and others) generally agree that summerfallow contributes to excessive O.M. losses, soil salinity, and wind and water erosion. The results of a simulation model at the University of Saskatchewan which specifically addresses the soil conservation/O.M. issue are indicative (Table 6.1). For example, in the heavy soils in the Red Deer area (CD#8), the simulation model indicates that the physical optimum summerfallow rotation (with no relative fertilizer cost increases) would be about once every 300 years (or, in effect, never) whereas the actual rotation is about once every eight years.

Table 6.1
SIMULATIONS VERSUS ACTUAL SUMMERFALLOW FREQUENCY - ALBERTA
(Years)

CD#	No. Fert. Price Increase		Fert. Price Increase*		Census	Survey
	Sandy Loam	Loam	Sandy Loam	Loam	1976	1980
2	6.25	30.0	3.90	15.79	3.1	2.62
8	37.5	300.0	11.11	150.00	11.0	8.10
11	25.0	300.0	9.68	75.0	8.6	5.10

* Increase of 5% per year.
Source: MAA/ECA, 1981, p. 98.

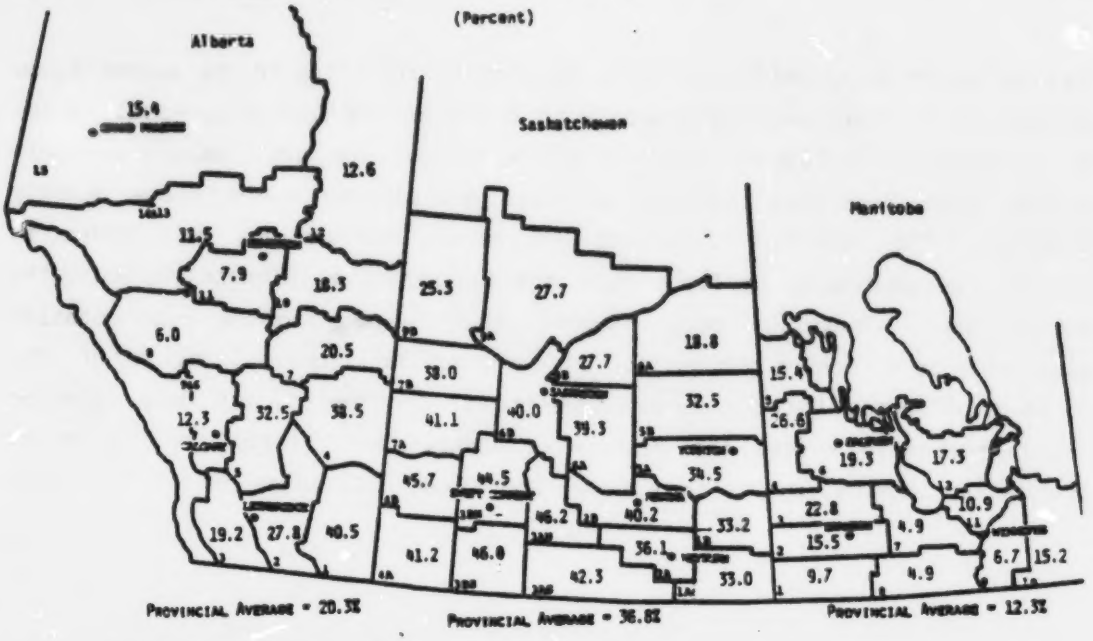
This is the physical rationale for a substantial reduction in the summerfallow acreage on the Prairies, particularly in the Black and Dark Brown soil zones, as illustrated in Figures 6.1 - 6.2 following. Two very recent economic studies also lend some support to these anticipated summerfallow acreage declines. The recently calculated B/C ratios for various soil zones in Alberta, as indicated in Table 6.2, are illustrative (Alberta Agriculture, August 1984). These B/C ratios suggest that lengthening the crop rotation would only be a loosing proposition in the Brown Soil Zone. In all other soil zones in Alberta, the discounted benefits of lengthening the crop rotation would apparently exceed the discounted costs, particularly the switch to continuous cropping in the Dark Brown and Black soil zones of the Province.

Table 6.2
BENEFIT-COST RATIOS WITH RESPECT TO
SUMMERFALLOW REDUCTIONS, BY SOIL ZONE - ALBERTA
(Discount Rate = 5%)

Soil Zone (Cropped Acres)	B/C Ratio
Brown (1500 acres)	
1/2-1/2 vs 1/3-2/3	0.80
1/2-1/2 vs 1/4-3/4	0.82
1/3-2/3 vs 1/4-3/4	0.43
Dark Brown(1110 acres)	
1/3-2/3 vs C/C*	1.31
1/4-3/4 vs C/C	1.44
1/3-2/3 vs 1/4-3/4	1.03
Black (North East)(600 acres)	
1/3-2/3 vs C/C	1.29
1/4-3/4 vs C/C	1.25
1/3-2/3 vs 1/4-3/4	1.38
Black (Central)(600 acres)	
1/3-2/3 vs C/C	1.45
1/4-3/4 vs C/C	1.60
1/3-2/3 vs 1/4-3/4	1.09
Luvisol (Yellow Area)(600 acres)	
1/3-2/3 vs C/C	1.19
1/4-3/4 vs C/C	1.20
1/3-2/3 vs 1/4-3/4	1.15

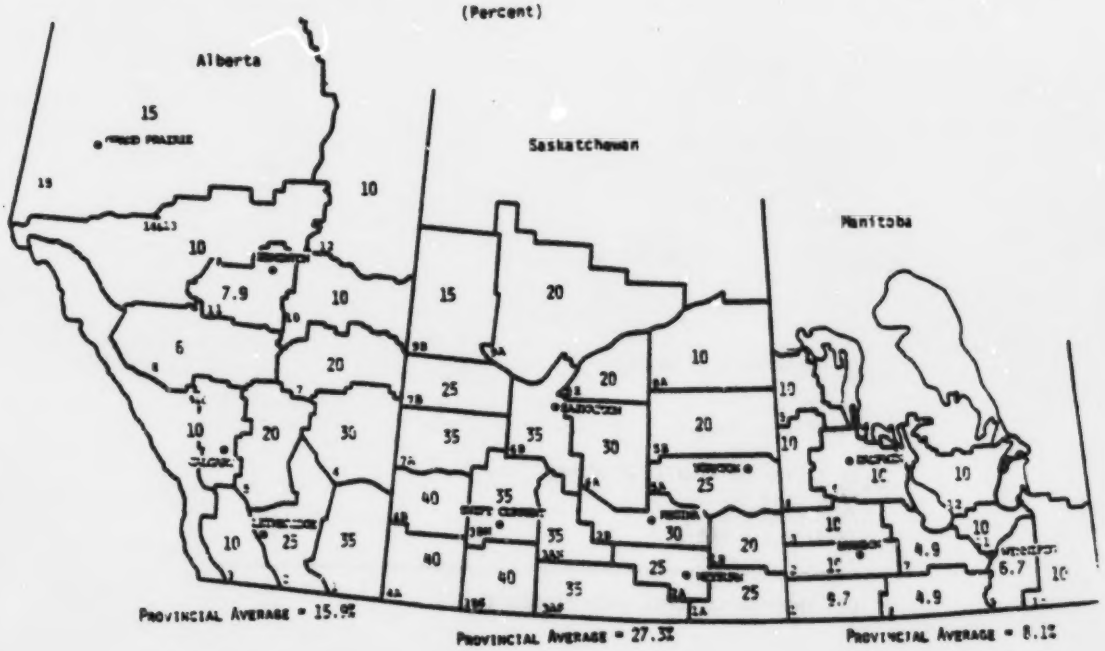
* C/C represents continuous cropping.

Figure 6.1. Proportion of Land Devoted to Summerfallow by Crop District, Prairie Provinces, 1981.



Source: Canada Grains Council (1982).

Figure 6.2. Projected Proportion of Land Devoted to Summerfallow by Crop District, Prairie Provinces, 1990.



Source: Canada Grains Council (1982).

And according to these estimates, although the expected shifts in the Brown soil zone would probably be very small, they would be somewhat larger for Gray Wooded soils; larger still for Dark Brown soils; and very large in the Black soil zone. This research is also consistent with recent work by Zentner (March 1984). With respect to the Brown soil zone in Saskatchewan, he found that:

> " ... Continuous wheat can only be recommended in periods of high expected grain prices and grain delivery quotas, and for producers who have the financial capability to purchase the extra resources associated with continuous rotations, it should only be considered with crop insurance and by producers who are willing or able to withstand major fluctuations in income. Producers who expect grain prices to be low, or who have high outstanding debts, low operating capital, or are highly averse to risk, will likely do best by continuing with the two-year fallow-wheat rotation."

These decision-variables will, in fact, affect the rate of change in crop rotations right across the Prairies.

With prevailing grain prices (which are relatively depressed) and assuming the appropriate discount rate is 10 percent/annum, our own guesstimate of the payoff to rotational changes is as follows:

Table 6.3
BENEFIT-COST RATIOS WITH RESPECT TO SUMMERFALLOW REDUCTIONS, BY SOIL ZONE - ALBERTA, ALTERNATIVE ESTIMATES
(Discount Rate = 5%)

Rotation			Soil Zone: Brown	Dark Brown	Black (NE)	Black (Central)	Luvisol
1/2-1/2	vs	1/3-2/3	.59	---	---	---	---
1/2-1/2	vs	1/4-3/4	.46	---	---	---	---
1/3-2/3	vs	C/C	---	.97	.95	1.07	.88
1/4-3/4	vs	C/C	---	1.07	.93	1.18	.89
1/3-2/3	vs	1/4-3/4	.32	.76	1.02	.81	.85

According to these calculations, shifts would still probably occur - but the shifts would not be pronounced. Thus, it would be our judgement that to actually achieve the desired relatively large shifts out of summerfallow (Figure 6.3), farm product prices would have to climb above current levels (despite freight rate increases), and various market and/or institutional constraints would have to be removed (restrictive quotas and the CWB acreage delivery formula).

This analysis, of course, ignores the potential long-term benefits of improved soil characteristics. The implications of this analysis may also be too pessimistic because this assessment does not allow for the introduction of a new (relatively low cost) input "package" which could control two or more soil degradation problems simultaneously. The potential impact of other very positive social-economic-technological and institutional changes which are already taking place, at least to some extent, may have also been unduly discounted (see especially Section 4.7 preceding).

At the same time, the on-farm economics of using a legume green manure in longer crop rotations could be even more positive. In addition to maintaining nitrogen levels, the potential opportunity for farmers to "grow their own nitrogen", instead of summerfallowing, would greatly reduce energy requirements on the Prairies and this would represent a very real cost saving (or, in effect, an income supplement). To at least put this potential into perspective, the following estimates have been prepared:*

Table 8.4
POTENTIAL ENERGY COST SAVINGS FOR CROP ROTATIONS WITH LEGUMES, BY SOIL ZONE & PROVINCE, 1983

Soil Type & Province	Diesel Equivalent		Fertilizer-N Equivalent		TOTAL SAVING ($,000)
	L/Acre	Total Saving ($,000)	lbs/Acre	Total Saving ($,000)	
SOIL TYPE:					
Brown	0.8	3,078	4.8	24,825	27,703
Dark Brown	3.0	18,884	10.1	58,100	72,784
Black	1.7	19,105	14.5	162,955	182,060
Luvisol	1.9	9,457	21.8	107,516	116,973
TOTAL		48,304		351,188	399,500
PROVINCE:					
B.C. (Peace)		425		4,828	5,253
Alberta		15,785		122,088	137,863
Saskatchewan		25,178		165,110	190,288
Manitoba		6,936		59,160	66,096
TOTAL		48,304		351,188	399,500

* Based on physical data prepared by Rice and Biederbeck (1983, p. 41) assuming the following changes to crop rotations:
Brown: FWFW to LWFW
Dark Brown: FWB to LWB
Black/Luvisol: FCBB to LCBB

For the Brown and Dark Brown soil zones, it is also assumed that an annual legume is available. The price of diesel is assumed to be 30 cents/L and the price of anhydrous ammonia (82% N2) is assumed to be 25 cents/lb. of Nitrogen.

The true significance of the Prairie-wide inclusion of a legume in crop rotations (if available and markets adjusted accordingly) can really only be appreciated by putting the above estimates into their proper context. We estimate that this development could reduce farm cash costs by 7%, and therefore increase net farm income by as much as 15-20 percent:

Table 8.5
ESTIMATED CHANGE IN FARM REVENUE AND INCOME WITH A FORAGE CROP IN CROP ROTATION, PRAIRIE PROVINCES

	% of Cash Costs	% of Farm Net Income
Alberta (incl. B.C. Peace)	6%	18%
Saskatchewan	8%	20%
Manitoba	5%	15%
TOTAL PRAIRIES	7%	15 - 20%

But most of these potential benefits have still not been realized. The Brown and Dark Brown soil zones, in particular, await the development of a profitable annual drought resistent legume (see following).

6.7 Research/Policy Implications

This overview identifies two broad research priorities:

1. The accurate determination, by region (soil type), of when organic matter losses (and what kind) affect productivity levels (yields) and to what extent, and
2. The successful development of an annual legume suitable for green manuring (substituting for summerfallow) across the Prairies. This annual legume would have a high N-fixing ability, rapid growth to provide effective ground cover against erosion and to produce large amounts of biomass, low liquification to facilitate easy incorporation into the soil, sufficient stand height to leave unincorporated strips for overwinter snow trapping and considerable drought-resistence (high water use efficiency) (Rice and Biederbeck, 1983, p. 39).

The on-going research in this regard is extensive, it simple lacks an intensive highly coordinated focal point.

Further program development should be coordinated with the required measures to control soil erosion as addressed in Section 4.7.

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APPENDIX A
DETAILS OF METHODS USED TO ESTIMATE RISK, EXTENT AND SEVERITY

A-1 Soil Salinization

A-1.1 Mapping Extent and Severity

The basic information sources were:

1. Manitoba - Salt Affected Soil Landscapes of Manitoba Map - 1:1,000,000 scale, by R.G. Eilers (1978), Canada - Manitoba Soil Survey.
2. Saskatchewan - Salinity Map of the Agricultural Region of Saskatchewan - 1:500,000 scale, by R.K. Ballantyne (in press), Saskatchewan Institute of Pedology.
3. Alberta - Dryland Seepage and Salinity Survey (Draft Map) of part of Southern Alberta, (ca. 1973), 1:750,000 scale, by Alberta Environment, Earth Sciences Division.

The legend and classification categories used to assess risk and extent are the same as those used by Ballantyne in Saskatchewan, and a trend indicator was added.

Several key questions had to be answered in order to produce the estimates, including:

1. What level of severity should be used to estimate yield reduction, knowing that severity usually grades from very low at the edge of an area to very strongly saline in the centre?
   Assumption: A moderately saline level (Electrical Conductivity = 6 mS/cm) was used to estimate yield reductions.

2. What guidelines should be used to estimate effects of salinity on yields?

   Assumption: Correlations developed by Holm (1982) in Saskatchewan are the best available.

   Effects of salinity on yields are shown in Table 3.5.

3. What rate of increase should be used to predict salinization over the next 25 years?

   Assumption: a) B Risk Class areas will increase by 10% in 25 years.
   b) C Risk Class areas will increase by 50% in 25 years.

Mapping Procedure

Saskatchewan

1. Reduce Ballantyne's maps to 1:2.5 million.

2. Transfer (some grouping) Risk Classes and assign Extent Classes.

Risk Classes	Extent Classes (Secondary Salinity)	Trend
A Low	N - 0%	x - static
B Mod.	1 - 0-7% (assume 3.5%)	y - increasing
	2 - 7-15% (assume 10%)	
C High	3,4,G - small areas, assume not cultivated	

3. Measure area of each extent class in each C.D. and apply to acres of improved land.

Alberta

1. Reduce Alberta Environment map to 1:2.5 million.

2. Group dryland salinity areas, transfer, and assign Risk and Extent Classes as per Saskatchewan legend.

3. Measure area of each extent class in each C.D. and apply to acres of improved land.

Manitoba

1. Reduce Manitoba Environment map to 1:2.5 million.

2. Transfer Risk Classes and assign Extent Classes as per Saskatchewan legend.

3. Estimate portion of secondary saline as being 10% of soil areas with saline inclusions.

4. Apply percentages to area of each polygon.

A-2 Soil Erosion

A-2.1 Mapping Extent and Severity

The basic information sources used were:

1. for Manitoba:
   - Generalized Soil Landscapes of Manitoba Map, at 1:1 million (Canada-Manitoba Soil Survey, 1983).
2. for Saskatchewan:
   - Generalized Soil Map of Saskatchewan, and derived maps, at 1:1 million (Shields, 1983).
3. for Alberta:
   - Wildlife Habitat Regions/Subregions of Alberta, map at 1:1 million and extended legend (Knapik and Westworth, 1984), describes landforms, soils and land use patterns.

Maps were interpreted for risk and amount of historic loss by extrapolating available information from soil survey maps and various research projects on a soil-landform basis as shown in the following matrix (used for Alberta and Saskatchewan). Historic losses in Manitoba were estimated by interpreting the general soil map and farm management practices to determine the extent of partial topsoil losses by wind and water erosion. These numbers were then converted to "total topsoil equivalent" values on an "equal-yield-reduction" basis.

Projections for amount of erosion losses in 25 years were based on interpretation of the Risk Classes using the following guidelines in Alberta and Saskatchewan.

Risk Class	Alta.-Sask. % Increase of Eroded Area in 25 Years
Low (A)	0
Moderate (B)	10
High (C)	30

Projections in Manitoba were based more on management practices and trends rather than soil/landform factors. Erosion was estimated to increase from 0 to 20 percent in various areas. The logic behind the projections in Alberta and Saskatchewan was that if X amount of soil was lost in 70 to 80 years of cultivation then approximately 0.3X would be lost in 25 years. This factor was then weighted to consider soil/landform and management variables to produce the estimates shown above.

Erosion rates are usually estimated by applying equations like the Universal Soil Loss Equation (USLE) or the "Wind Loss Equation", however the research needed to identify the many factors used in these equations is only just beginning to be done in Western Canada (van Vliet, 1983; Chanasyk and Woytowich, 1983; DeJong, 1983; Slavinsky, 1983; G. Coen, Ag. Canada, Edmonton, pers. comm.; R. Howitt, Alta. Research Council, pers. comm.).

Effects on Yields

The following table relating amount of topsoil loss to relative yields of wheat, barley and canola by soil zone was developed by reviewing available research data and guesstimating. Loss calculations for a typical farm in a Census Division required knowledge of: the soil mix, the crop mix, and the amount of erosion in the C.D.. Guidelines used for soil distirbution by C.D. also had to be guesstimated (following tables).

Table A-1
INTERPRETATION OF EROSION RISK, EXTENT OF HISTORIC LOSSES, AND EROSION TRENDS IN SASKATCHEWAN AND ALBERTA

Landform	Slope			
	1 - 3%	4 - 9%	10 - 15%	16 - 30%
BROWN SOIL ZONE				
Morainal	C1y	C1y	C2y	C3y
Lacustrine	B1y	C2y	---	---
Fluvial	C2y	C2y	C3y	---
(Solonetz)	B1y	B2y	---	---
DARK BROWN SOIL ZONE				
Morainal	---	B2y	C2y	C3y
Lacustrine	B1y	B2y	---	---
Fluvial	C2y	C2y	C3y	---
(Solonetz)	B1y	B1y	---	---
BLACK SOIL ZONE				
Morainal	B1x B1y (south)	B1y	C2y	C3y
Lacustrine	A1x	B2y	---	---
Fluvial	B1y	B1y	C3y	---
GRAY ZOIL ZONE				
Morainal	---	B1y	C2y	C3y
Lacustrine	A1y	---	---	---
Fluvial	C1y	C2y	---	---
(Solonetz)	B1y	---	---	---

Table A-2
ESTIMATED EFFECTS OF EROSION ON YIELDS

Soil / Crop	Amount of Topsoil Eroded		
	100% loss*	50% loss*	Not Eroded
	----- Relative Productivity (%) -----		
Brown Chernozemics:			
Wheat	50	80	100
Barley	50	80	100
Dark Brown-Black Chernozemics:			
Wheat	70	90	100
Barley	70	90	100
Canola	50	80	100
Gray and Dark Gray Luvisols:			
Wheat	40	70	100
Barley	40	70	100
Canola	20	50	100
Solonetzic Soils:			
Wheat	10	40	100
Barley	10	40	100
Canola	0	30	100

* Estimates of historic erosion are expressed as acres of land with total topsoil removal. Lands with partial topsoil removal were weighted (on an equivalent yield reduction basis) and proxied as acres of total removal.

Table A-3
DISTRIBUTION OF SOILS BY CENSUS DIVISION - ALBERTA

Census Division	% of Improved Acres				
	Brown	Dark Brown	Black	Gray	Solonetz
1	90	--	--	--	10
2	40	60	--	--	--
3	--	40	60	--	--
4	80	--	--	--	20
5	--	70	30	--	--
6	--	--	100	--	--
7	--	40	40	--	20
8	--	--	50	50	--
9	--	--	60	40	--
10	--	--	80	10	10
11	--	--	70	30	--
12	--	--	--	100	--
13	--	--	20	70	10
14	--	--	--	100	--
15	--	--	--	80	20

Table A-4
DISTRIBUTION OF SOILS BY CENSUS DIVISION - SASKATCHEWAN

Census Division	% of Improved Acres				
	Brown	Dark Brown	Black	Gray	Solonetz
1	--	40	50	--	10
2	30	50	--	--	20
3	100	--	--	--	--
4	100	--	--	--	--
5	--	--	100	--	--
6	--	60	40	--	--
7	50	40	--	--	10
8	100	--	--	--	--
9	--	--	80	20	--
10	20	--	80	--	--
11	--	100	--	--	--
12	--	80	20	--	--
13	20	50	20	--	10
14	--	--	10	90	--
15	--	10	30	60	--
16	--	--	40	60	--
17	--	--	20	70	10

A-3 Soil Acidification

NOTE: Mapping and summary numbers for acid soils recognizes total acid soils - including those that were acid before farming and those where pH was lowered by farming practices. No baseline information or estimates are available to identify only the "degraded" portion. The annual increase predictions provide some measure of the rate of degradation.

A-3.1 Mapping Extent and Severity

The basic information sources were:

1. Manitoba - no significant acreages of acid soils at present
   - projected changes were based on work by D.L. Wotten (Man. Dept. of Environment, and Workplace Safety and Health).
2. Saskatchewan - Surface pH of Saskatchewan Soils - map by Rostad et al., 1983.
3. Alberta - summary of soil test data by Penney et al. (1977), and interpretation of general soil maps.

A similar legend to that used for salinity and erosion was used for the Acid Soils Map to indicate Risk, Extent of Acid Soils, and Trend.

Increasing acidification of soils is primarily due to the acidifying effects of nitrogen fertilizers.

Acidifying Effect of Fertilizer Expressed as Lime Requirement to Neutralize Acidification

- 1 lb. of N from Ammonium Sulphate = 5.35 lb. of lime
- 1 lb. of N from anhydrous ammonia, urea or ammonium nitrate = 1.8 lb. of lime
- 50 to 100 lb. of N per year can drop soil pH by 0.5 to 1.5 units in 10 years

Effects of pH level on yields were determined by using the guidelines shown in the following table. These were developed by reviewing various data sources and doing some guesstimating.

Table A-5
EFFECTS OF ACIDITY ON YIELDS

Crop	pH Range (in H O) 5.1-5.5	5.6-6.0	> 6.0
	----- Relative Productivity (%) -----		
In Manitoba, Saskatchewan, Central Alberta:			
Wheat	85	95	100
Barley	75	90	100
Canola	75	90	100
In Peace River Region:			
Wheat	85	95	100
Barley	75	90	100
Canola	85	95	100

Data Sources:
1. H. Ukrainetz, 1969, 1979, 1981, 1982, 1984. Agriculture Canada.
2. P. Hoyt, 1982.
3. D. Penney et al. 1977.
4. D. Penney, personal communication July, 1984.

APPENDIX B
REGIONAL GROSS CROP REVENUE ESTIMATES

B-1 Basic Methodology

The regional gross crop revenue estimates developed for the purposes of this study have been prepared using the following formula:

$$\text{Total Crop Value/Improved Acre} = \frac{\left(\frac{\text{Total Crop Acreage}}{\text{Wheat-Barley-Canola Acreage}}\right)\left(\text{Wheat-Barley-Canola Value}\right)}{\text{Improved Land}}$$

where the value of each major crop is defined by: Area x Yield x Price

and where the following data sources were utilized:

Areas - Census of Agriculture, 1981 (for 1980)
Yields - respective provincial Agriculture Yearbooks (for 1982)**
Prices - "average" prices, as discussed following.

Only wheat, barley, and canola production were explicitly considered because the value of these crops has been determined to be typical, i.e. average. This short-cut approach does not result in any glaring inaccuracies.*

Yield estimates for the three principal crops for the year 1982 were taken directly from provincial Agriculture Yearbooks** except that in most cases the estimates for the respective Census Divisions had to be estimated from reported yields for Crop Reporting Districts. For Manitoba and Alberta, aerial

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* DRIE/PFRA, Land Degradation and Soil Conservation Issues on the Canadian Prairies: An Overview, Regina, November 1982. The authors of this study also tested this simplification for the province of Manitoba - which publishes value of production estimates and has a lower percentage of its cropland in wheat, barley, and canola. In this case, the procedure also worked remarkably well.

** For the B.C. Peace area, the yield estimates were based on the years 1980-81.

overlays consistent with the Census of Agriculture, 1980 were used. For Saskatchewan, a previously-developed Crop District/Census Division transformation table was employed.*

The prices selected are largely based on the professional judgement of the authors regarding the future real price of these particular crops, giving very careful consideration to the prevailing price structure in mid-1984. The prices assumed are as follows:

Wheat	$175/tonne	($4.76/bushel)
Barley	115/tonne	(2.50/bushel)
Canola	350/tonne	(7.94/bushel)

The estimates generated in this manner are summarized in Table 8-1 while their spatial distribution is illustrated in accompanying Figure 8-1.

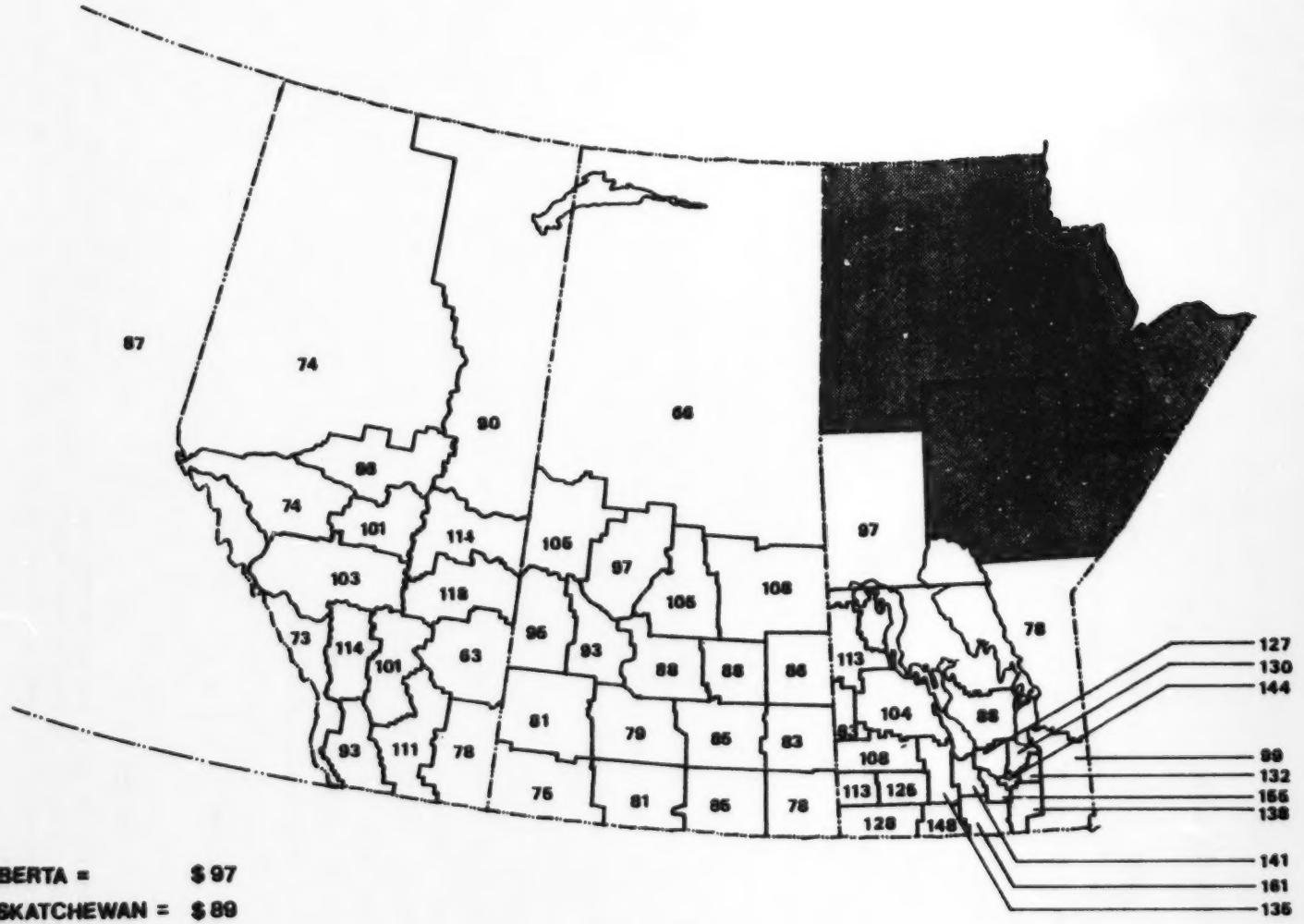
---

* Marv Anderson & Assoc., Saskatchewan Drought Studies: Economic Study Parameters, Study Element 2, Saskatchewan/ORIE, Regina, March 1983, p. 8-9.

Table B-1
AVERAGE ANNUAL GROSS CROP REVENUE
PER IMPROVED ACRE, PRAIRIE PROVINCES, EARLY
1980'S, BY CENSUS DIVISION ($/Acre)

Census Division	Alberta	Saskatchewan	Manitoba
1	78	78	99
2	111	85	138
3	93	81	161
4	63	75	148
5	101	83	128
6	114	85	113
7	118	79	125
8	103	81	135
9	73	86	141
10	114	88	155
11	101	88	144
12	90	93	132
13	88	95	130
14	74	108	127
15	74 (87)*	105	108
16	-	97	83
17	-	105	104
18	-	-	88
19	-	-	78
20	-	-	113
21	-	-	97
22-23	-	-	-

* B.C. Peace area average indicated in brackets.



ALBERTA = $ 97
SASKATCHEWAN = $ 89
MANITOBA = $ 124
B.C. (PEACE) $ 87

Figure B·1

AVERAGE ANNUAL GROSS CROP REVENUE PER IMPROVED ACRE, PRAIRE PROVINCES, BY CENSUS DIVISION, EARLY 1980.

B-2 Qualifications

Annual gross crop revenue estimates per improved acre, by region, are utilized in this study to assign a dollar value to the annual marginal cost of various types of soil degradation on the Prairies. Given the resources available for this study, this is our "best guess". At the same time, various limitations to this approach should also be acknowledged at the outset:

1. The 1982 yield estimates may not represent an "average" year throughout the Prairies'. Typically, some areas are too dry, too wet, subject to frost, etc.. This is a study limitation; not an inherent methodological shortcoming. To establish "normal" 1984 (or future) yields, trend lines (via regression) could be developed using existing time series data.

2. The procedure utilized implicitly assigns a zero-value to improved pasture and other improved land (excluding summerfallow). Only crop land is valued to generate an average value per improved acre, and

3. Related to (2), the incremental value generated directly from livestock production (but indirectly from crop production) is also ignored. The present authors tried to circumvent this limitation by utilizing estimated regional gross receipts per improved acre. To no avail.* This alternative procedure would only be satisfactory if livestock revenues could be adjusted downward such that they only reflected value-added in the livestock sector which was generated from locally-produced feed grains and if crop revenues could be adjusted to fully account for inter-regional grain movements and grain inventory fluctuations.

---

* In this context, the use of income tax data for farm tax filers for the period 1976 - 1982 was also employed to develop "normal" annual regional gross farm receipts. But this independent data source (versus Census data) is also subject to various limitations which limits its use in the above context.

Further, the basic analysis in the accompanying text also implicitly assumes that improved land use remains the same for the next 25 years. Specific land use changes are considered only as noted. By using regional averages, the analysis also ignores any possible correlation between a particular land use on improved land and a particular soil degradation problem.

And, finally, it bears repeating that it is also being assumed that soil degradation affects "productivity" (which, in this report, is synonomous with "yields") which directly affects gross revenue (1:1) which, in turn, directly affects net farm revenue (again 1:1) which, when interpreted as a loss in value-added, can be equated to a net "social" (or GDP) loss. Or, in other words, the basic analysis also ignores any simultaneous (off-setting or additional) cost-of-production changes.

Most of these qualifications, if valid, would generally tend to bias <u>downward</u> the economic estimates generated in the main body of this report.

APPENDIX C

THE ON-GOING ON-FARM COSTS OF SOIL CONSERVATION ON THE PRAIRIES

As emphasized throughout this report, the estimated costs of various types of soil degradation on the Prairies are not, strictly speaking, additive. This is equally true of the benefits and costs of numerous amiliorative measures addressed in the main body of this report. Many of the physical characteristics (and related economic implications) are interactive.

Thus, for the purposes of this study, it is hypothesized that the value of chemical fertilizer which is being applied by farmers (for a given cropping intensity and technology) which is not being translated into yield improvements might at least suggest how much soil conservation, in total, is presently costing Prairie farmers annually.*

The calculating procedure employed by the authors is explained briefly following:

1. Crop mixes and estimates of fertilizer use for the three Prairie provinces, by Census Division, were obtained from the 1971 and 1981 Census of Agriculture. These data were then made comparable between Census periods by adjusting for changes in the total cropped area and for changes in summerfallowing versus stubble cropping.**

---

* Assuming that farmers are simply trying to maintain soil quality in each and every C.D.. It is also recognized, a priori, however, that there is an additional cost which is not (or cannot) be captured by using this proxy accounting process.

** Regional C.R.D's for Alberta indicate that fertilizer application rates on stubble are approximately twice the rate on summerfallow. The authors assume that this difference is equally applicable to all provinces and C.D.'s on the Prairies.

2. Weighted average yield increases over the 1971 to 1981 period by Census Division for wheat, barley and canola were estimated using data from the Canada Grains Council.* These estimated yield increases were applied to 10-year (1972-1981) yield averages for each of the three Prairie provinces to determine incremental yields over time.

3. The authors assume that 40 percent of this incremental yield is attributable to fertilizer while the remaining 60 percent is attributable to improvements in crop varieties, machinery, herbicides and management.**

4. The fertilizer application necessary to achieve the fertilizer-induced yield increases over time (i.e. 40 percent of the total yield increase) were calculated using a crop response model which estimates the yield response of wheat, barley and canola to incremental nitrogen applications, by soil type (Brown, Dark Brown, Black/Gray Wooded).***

5. The amount of additional fertilizer needed to increase observed yields was deducted from fertilizer use in 1980.

6. Finally, the 1970 fertilizer application rates (adjusted for crop area and changes in stubble-fallow cropping) were subtracted from the 1980 rates (adjusted downward to net out their contribution to yield increases).

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* Canada Grains Council, Prospects for the Prairie Grain Industry, 1990, Winnipeg, November, 1982, p. 40.

** Marv Anderson & Associates Ltd., An Analysis of Research and Agricultural Productivity in Alberta, ECA, Edmonton, 1983, p. 98. This study also pointed out the need for additional research on this topic.

*** Correspondence with Alberta Agriculture personnel, Edmonton, July 1984. These response functions are specific to Alberta but they are also very similar to estimated fertilizer response functions in Saskatchewan (Saskatchewan Provincial Soil Testing Laboratory). The Alberta function for the black soil zone is also generally consistent with comparable data from Manitoba (See Yield-Nitrogen Supply Tables for Wheat, Barley, Oats used by the Manitoba Provincial Soil Testing Laboratory, Winnipeg, September 1982). Thus, the mathematical functions representative of soils in Alberta were used for the entire Prairie region.

Resulting Table C-1 and accompanying Figure C-1 at least suggest how much chemical fertilizer is probably being applied (for a given land base, cropping intensity, and technology) that is not being translated into improved yields. The provincial averages range from 50% in Alberta to almost 70% in Saskatchewan.

The estimated annual cost of this fertilizer is: ($ current)

Alberta	79.4 million
Saskatchewan	140.3
Manitoba	89.9
TOTAL	$309.6 million

A recent study by the Senate Standing Committee on Agriculture (June 1984, p.111) suggests that this cost is about $239 million; somewhat less than our own estimates.

But further assuming that 15% of the lost production simply cannot be recovered by additions of fertilizer, the comparative "bottom-line" estimates are virtually identical:

	This Study	Senate Study
Fertilizer Use	$309.6 M	$239 M
plus 15%	46.4	35.8
TOTAL	$356 M	$274.8 M

Thus, it is our professional judgement that these preliminary calculations can be considered generally indicative of what farmers are presently spending on chemical fertilizers to maintain their land base, irrespective of precisely why this expenditure is necessary.

These baseline calculations are useful when evaluating the reliability of the various degradation cost estimates in the main body of this report.

Table C-1
ESTIMATED FERTILIZER USE TO OFF-SET SOIL QUALITY LOSSES ON THE PRAIRIES, 1980

	ALBERTA			SASKATCHEWAN			MANITOBA		
Census Division	Total (tonnes)*	% of Total Use	Cost/Acre Cropped**	Total (tonnes)*	% of Total Use	Cost/Acre Cropped**	Total (tonnes)*	% of Total Use	Cost/Acre Cropped**
1	10765	61.1	3.44	20024	77.7	4.08	1875	56.4	3.21
2	23510	36.5	4.16	11704	70.8	2.11	25528	67.6	11.00
3	11367	31.6	3.80	4714	41.6	1.16	51401	60.0	11.74
4	1716	28.1	.54	0	0	0	28450	71.2	10.81
5	25107	47.4	4.24	17109	73.1	3.30	27929	63.0	6.48
6	13131	23.1	3.02	27104	79.1	4.00	6691	55.5	4.32
7	33205	56.8	5.17	6642	50.8	1.41	23432	59.0	9.16
8	27682	56.8	5.99	7636	42.6	1.34	21486	56.3	8.38
9	(123)	0	0	16146	69.6	3.87	16891	65.6	10.67
10	63052	67.0	6.82	21106	77.0	4.31	24590	74.8	15.03
11	23107	47.4	4.36	20967	72.6	3.88	1553	68.3	9.35
12	10648	58.4	3.65	18450	75.5	4.16	7587	63.6	6.98
13	17534	47.8	3.63	29119	70.2	5.32	7185	68.2	8.69
14	225	18.5	.51***	56670	69.8	8.36	8128	52.6	6.53
15	60467	67.8	5.47	58831	75.1	8.20	33640	71.8	8.45
16				25665	72.6	5.57	8166	70.3	5.71
17				26041	66.7	6.41	11421	47.6	4.63
18				75	48.4	2.22	5017	40.6	3.10
19							(135)	0	0
20							14767	71.6	9.42
21							(1181)	0	0
PROVINCE	321393	50.0	3.81	368003	69.9	4.84	324421	62.7	8.23

* Based on the difference between fertilizer application rates in 1980 and 1970 respectively, adjusted for changing cropping intensities and yields. See text for details.

** $1984.

*** Also expected to reflect conditions in the B.C. Peace region.

Basic Source: Statistics Canada, Census of Agriculture, 1970 and 1980, Ottawa, 1971 & 1981 respectively.

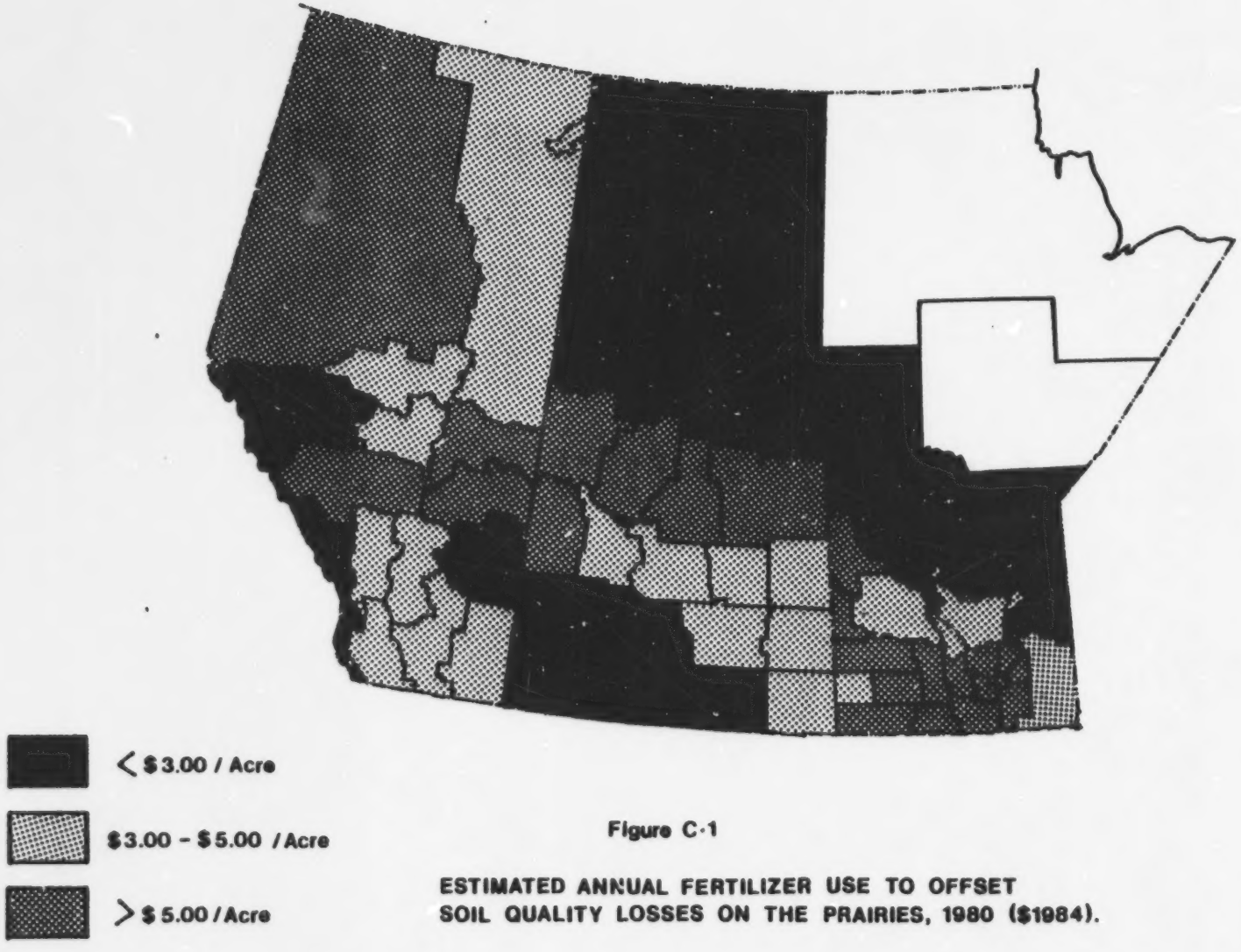
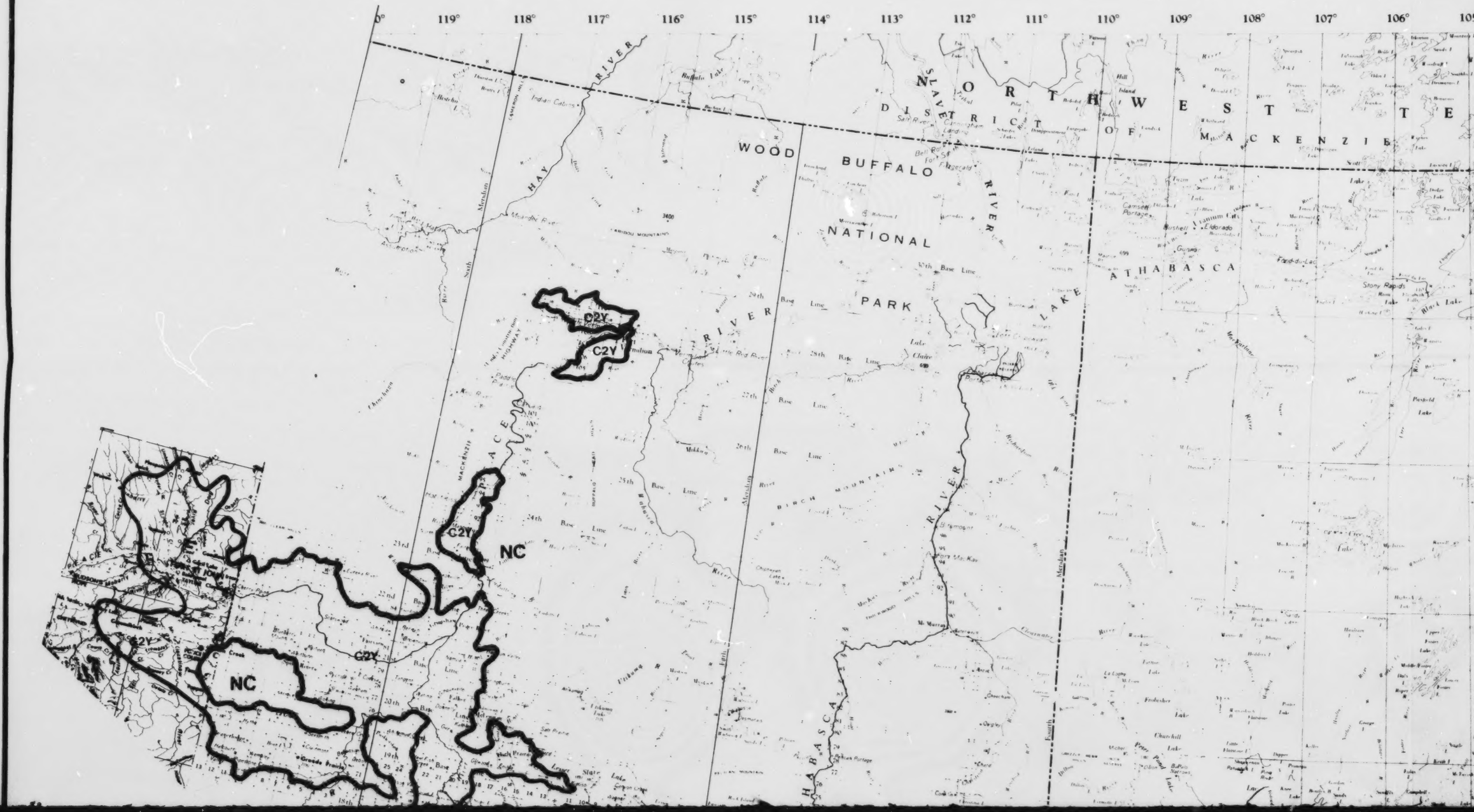


Figure C-1

ESTIMATED ANNUAL FERTILIZER USE TO OFFSET SOIL QUALITY LOSSES ON THE PRAIRIES, 1980 ($1984).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HAY RIVER
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SLAVE RIVER
PEACE RIVER
ATHABASCA RIVER
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Meridian
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LAND DEGRADATION IN THE GRAIN GROWING REGION OF WESTERN CANADA

SOIL EROSION

LEGEND

RISK	% OF AREA WITH "A" HORIZON 100% ERODED	TREND
A - LOW B - MODERATE C - HIGH	N - <1% 1 - <15% 2 - 15% - 40% 3 - >40%	X - STATIC Y - INCREASING

NC - NOT CONSIDERED (GENERALLY NOT A GRAIN PRODUCTION AREA)
ID - IRRIGATION DISTRICT (NOT CONSIDERED)

COMPILED BY.

PEDOCAN LAND EVALUATION LTD. (EDMONTON, ALTA.)
T.J. CONSULTING (NORTH BATTLEFORD, SASK.)
NIELSEN AND PITURA CONSULTING (DOMAIN, MAN.)

SCALE: 1:2,500,000

JULY, 1984

ALBERTA

SASKATCHE

ROCKY MOUNTAIN

WILDERNESS PROVINCIAL PARK

JASPER NATIONAL PARK

BANFF NATIONAL PARK

BIRCH MOUNTAIN

ATHABASCA RIVER

EDMONTON

NC

C2Y

C1Y

B1Y

A1Y

A1X

C3Y

B2Y

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NC - NOT CONSIDERED (GENERALLY NOT A GRAIN PRODUCTION AREA)
ID - IRRIGATION DISTRICT (NOT CONSIDERED)

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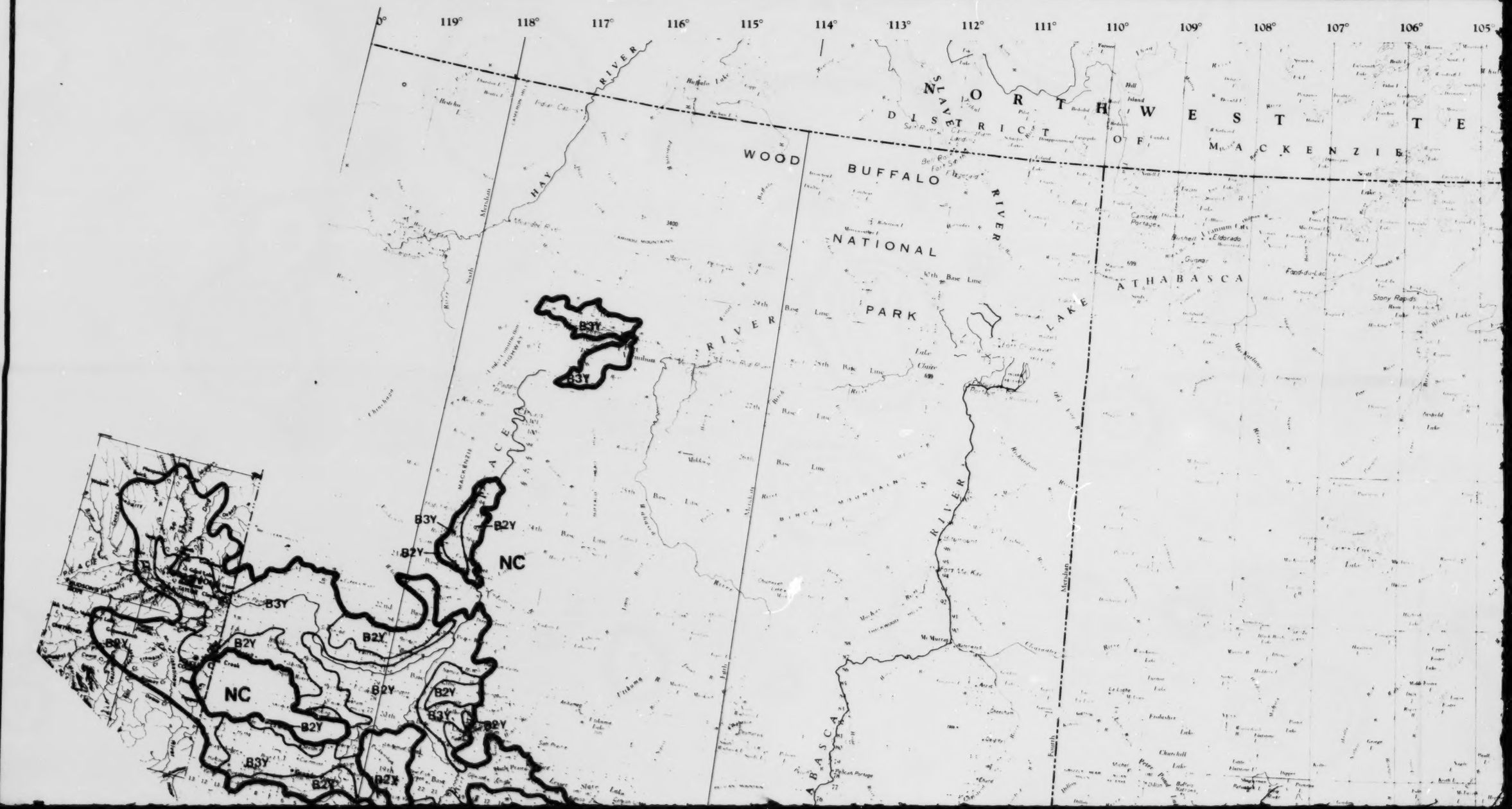
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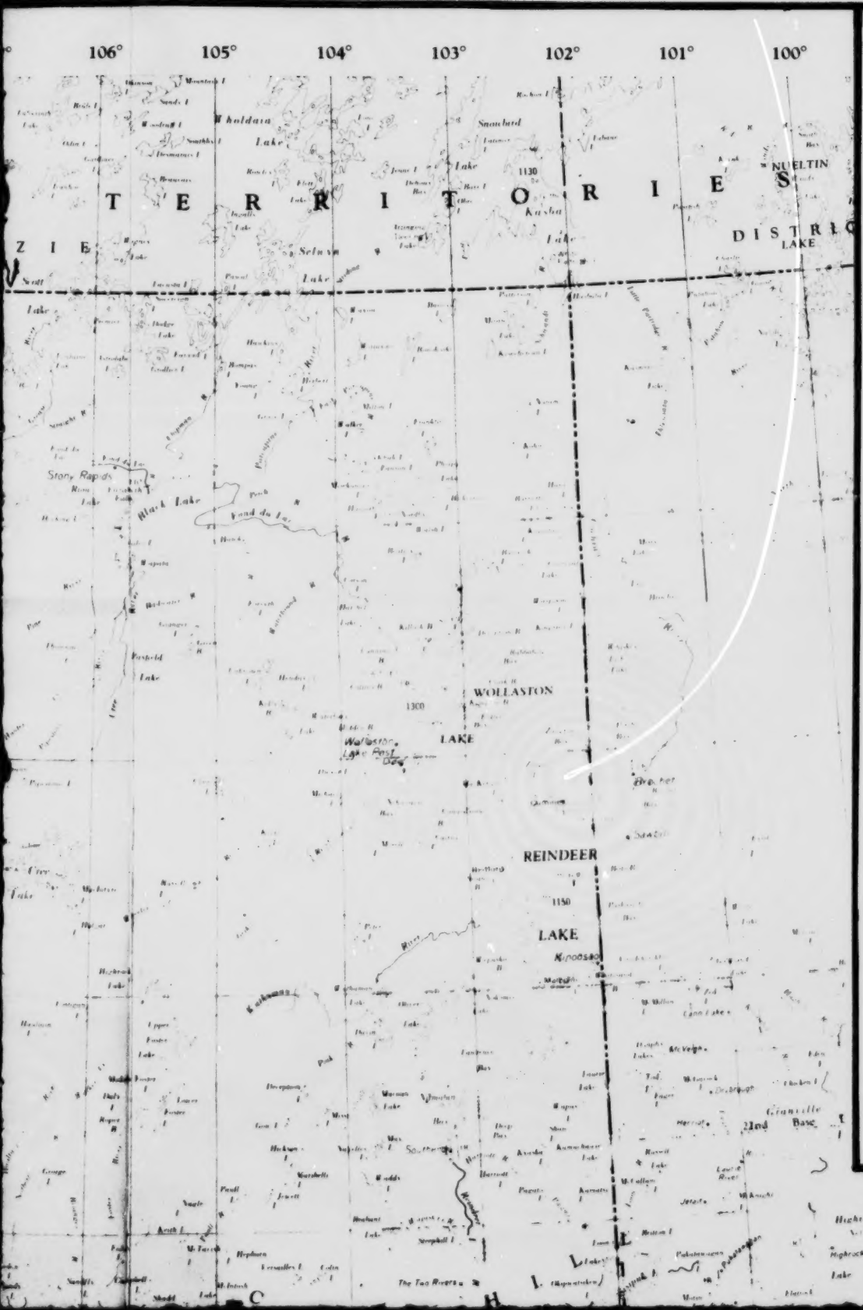

LAND DEGRADATION IN THE GRAIN GROWING REGION OF WESTERN CANADA

ACID SOILS

LEGEND

RISK	% OF AREA WITH pH < 6.0	TREND
A - LOW B - MODERATE C - HIGH	N - < 1 % 1 - < 15 % 2 - 15 % - 40 % 3 - > 40 %	X - STATIC Y - INCREASING

NC - NOT CONSIDERED (GENERALLY NOT A GRAIN PRODUCTION AREA)
ID - IRRIGATION DISTRICT (NOT CONSIDERED)

COMPILED BY.

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PURCELL MOUNTAINS
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RIVER
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Saskatoon
Kimberley
Cranbrook
Nelson
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Castlegar
Creston
Sandpoint
WASHINGTON
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MONTANA
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B1Y
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LAKE WINNIPEGOSIS
LAKE WINNIPEG
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NORTH DAKOTA
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ED STATES OF AMERICA
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JULY, 1984

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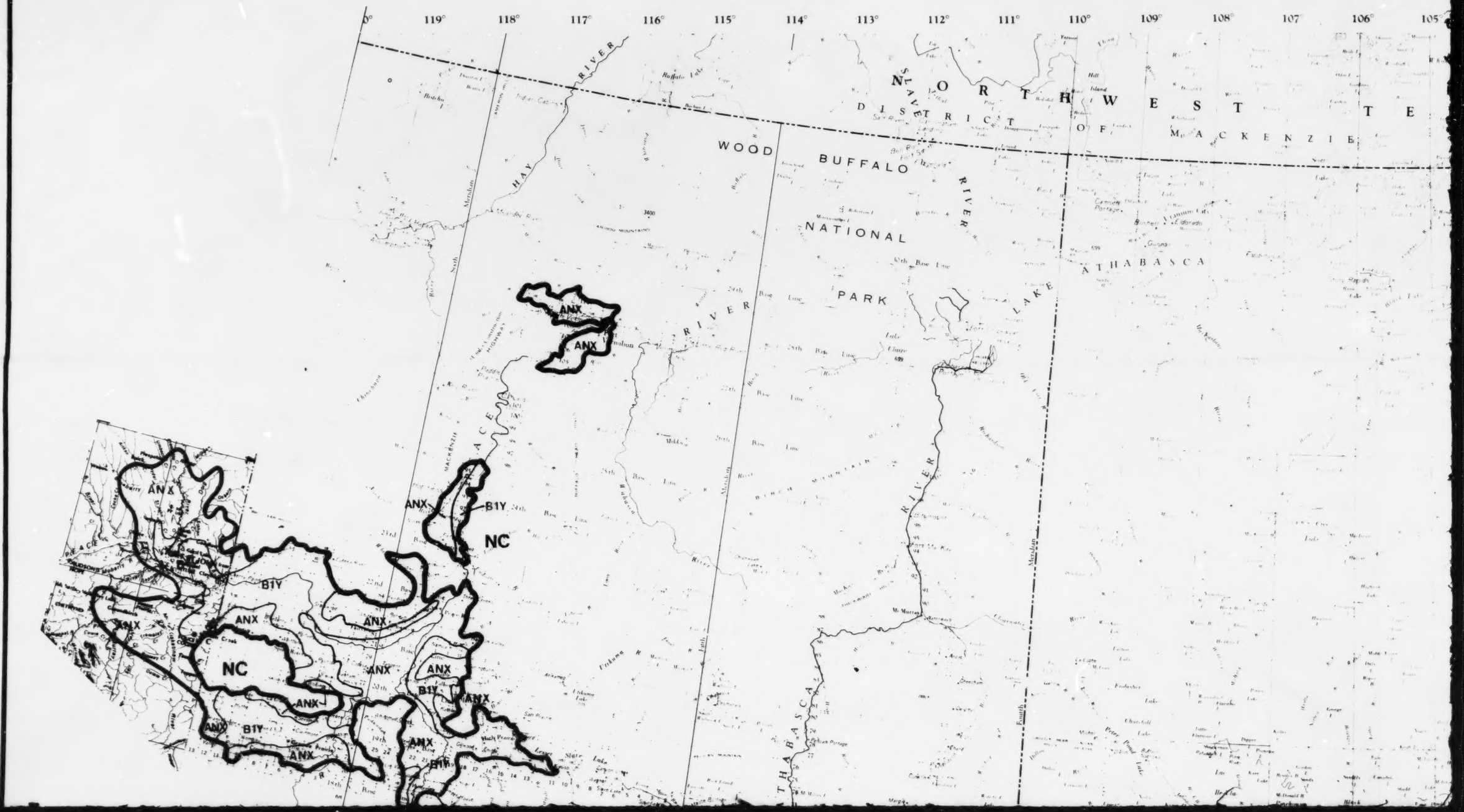
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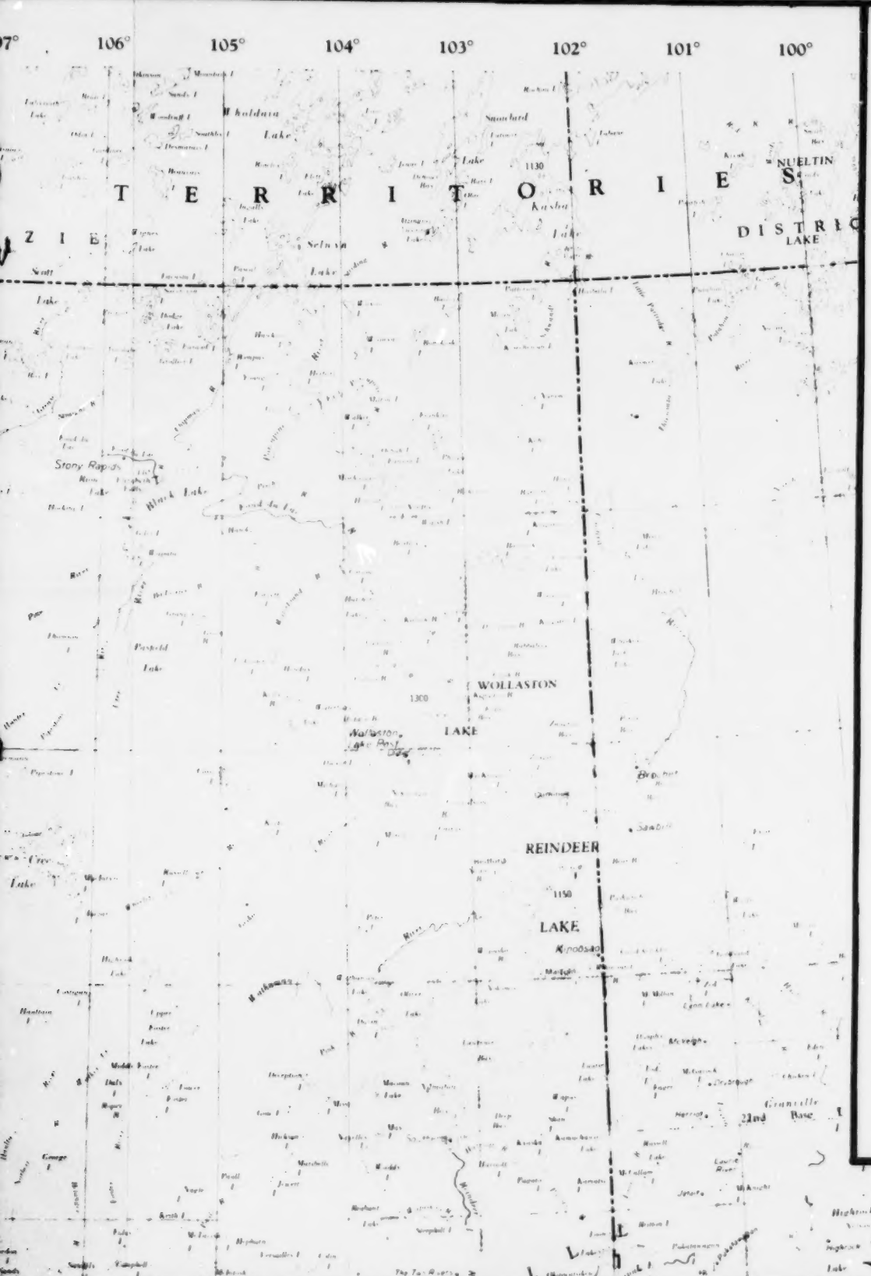

LAND DEGRADATION IN THE GRAIN GROWING REGION OF WESTERN CANADA

SALINE SOILS

LEGEND

RISK CLASS	% OF AREA WITH SALINE SOILS	TREND
A - LOW B - MODERATE C - HIGH	N - <1 % 1 - <7 % 2 - 7% - 15 % ■ - > 15 %	X - STATIC Y - INCREASING

NOTE

PROPORTION OF TOTAL SALINE SOILS THAT IS ATTRIBUTABLE TO SECONDARY SALINIZATION ESTIMATED AS 25% IN A 'B' RISK CLASS AREA AND 50% IN A 'C' RISK CLASS AREA IN SASKATCHEWAN AND ALBERTA
IN MANITOBA 10% OF TOTAL SALINE SOILS IS ATTRIBUTED TO SECONDARY SALINIZATION IN ALL RISK CLASSES
NC - NOT CONSIDERED (GENERALLY NOT A GRAIN PRODUCTION AREA)
ID - IRRIGATION DISTRICT (NOT CONSIDERED)

COMPILED BY:

PEDOCAN LAND EVALUATION LTD. (EDMONTON, ALTA.)
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NIELSEN AND PITURA CONSULTING (DOMAIN, MAN.)

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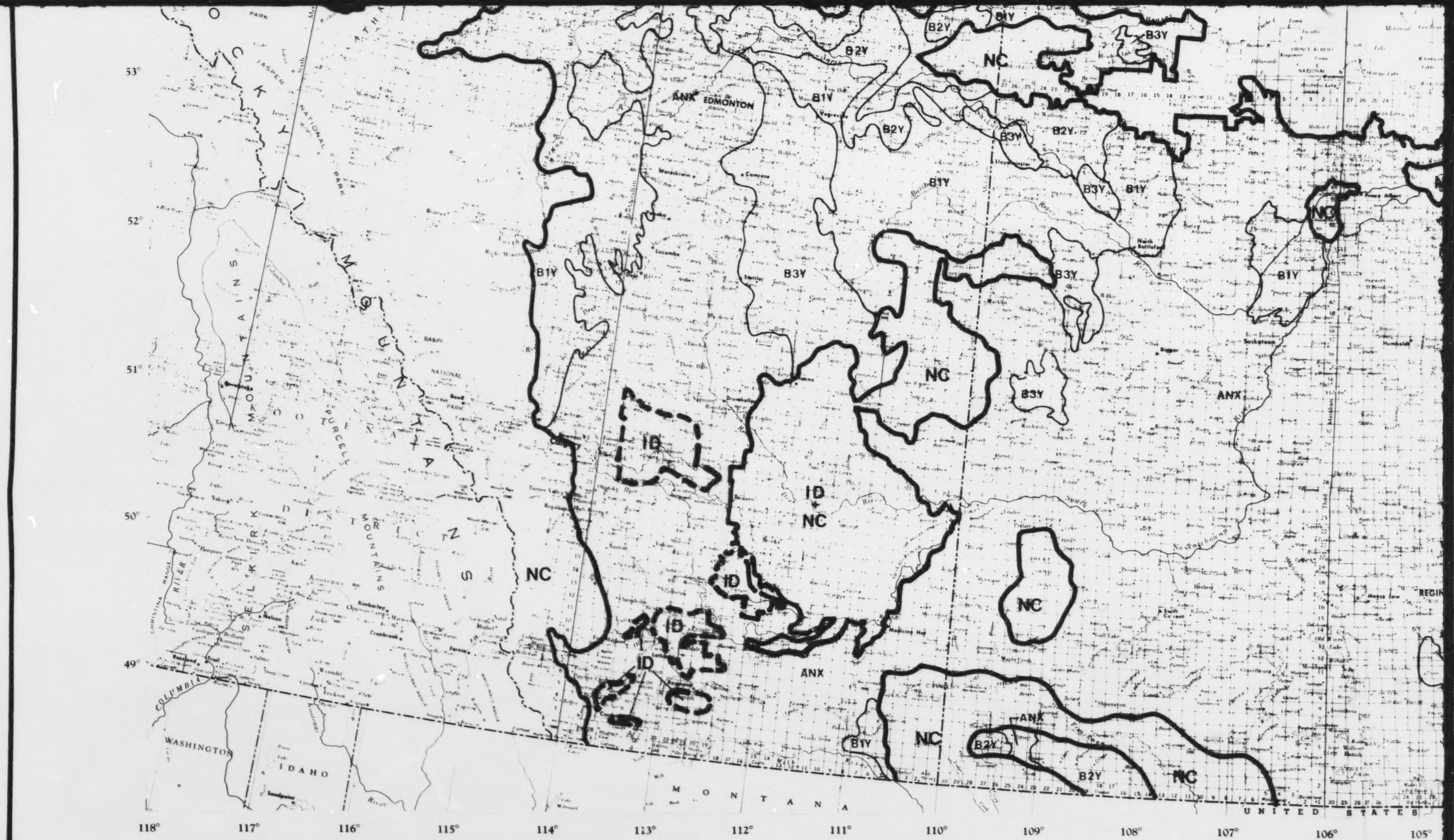
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BANFF NATIONAL PARK
WATERTON LAKES NATIONAL PARK
GLACIER NATIONAL PARK
SELKIRK MOUNTAINS
PURCELL MOUNTAINS
COLUMBIA MOUNTAINS
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MINNESOTA
SASKATCHEWAN
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WINNIPEG
LAKE WINNIPEGOSIS
LAKE MANITOBA
LAKE OF THE WOODS
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ALBERTA

SASKATCH

ROCKY MOUNTAINS

ATHABASCA

EDMONTON

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NC
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JASPER NATIONAL PARK
BANFF NATIONAL PARK
KOOTENAY

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PROPORTION OF TOTAL SALINE SOILS THAT IS ATTRIBUTABLE TO
SECONDARY SALINIZATION ESTIMATED AS 25% IN A 'B' RISK CLASS AREA AND
50% IN A 'C' RISK CLASS AREA IN SASKATCHEWAN AND ALBERTA
IN MANITOBA 10% OF TOTAL SALINE SOILS IS ATTRIBUTED TO SECONDARY
SALINIZATION IN ALL RISK CLASSES
NC - NOT CONSIDERED (GENERALLY NOT A GRAIN PRODUCTION AREA)
ID - IRRIGATION DISTRICT (NOT CONSIDERED)

COMPILED BY.

PEDOCAN LAND EVALUATION LTD. (EDMONTON, ALTA.)
T.J. CONSULTING (NORTH BATTLEFORD, SASK.)
NIELSEN AND PITURA CONSULTING (DOMAIN, MAN.)

SCALE : 1: 2,500,000

JULY, 1984

SASKATCHEWAN

MANITOBA

ONTARIO

REINDEER LAKE

CHURCHILL

LAKE WINNIPEGOSIS

LAKE MANITOBA

NC

B2X

B1Y

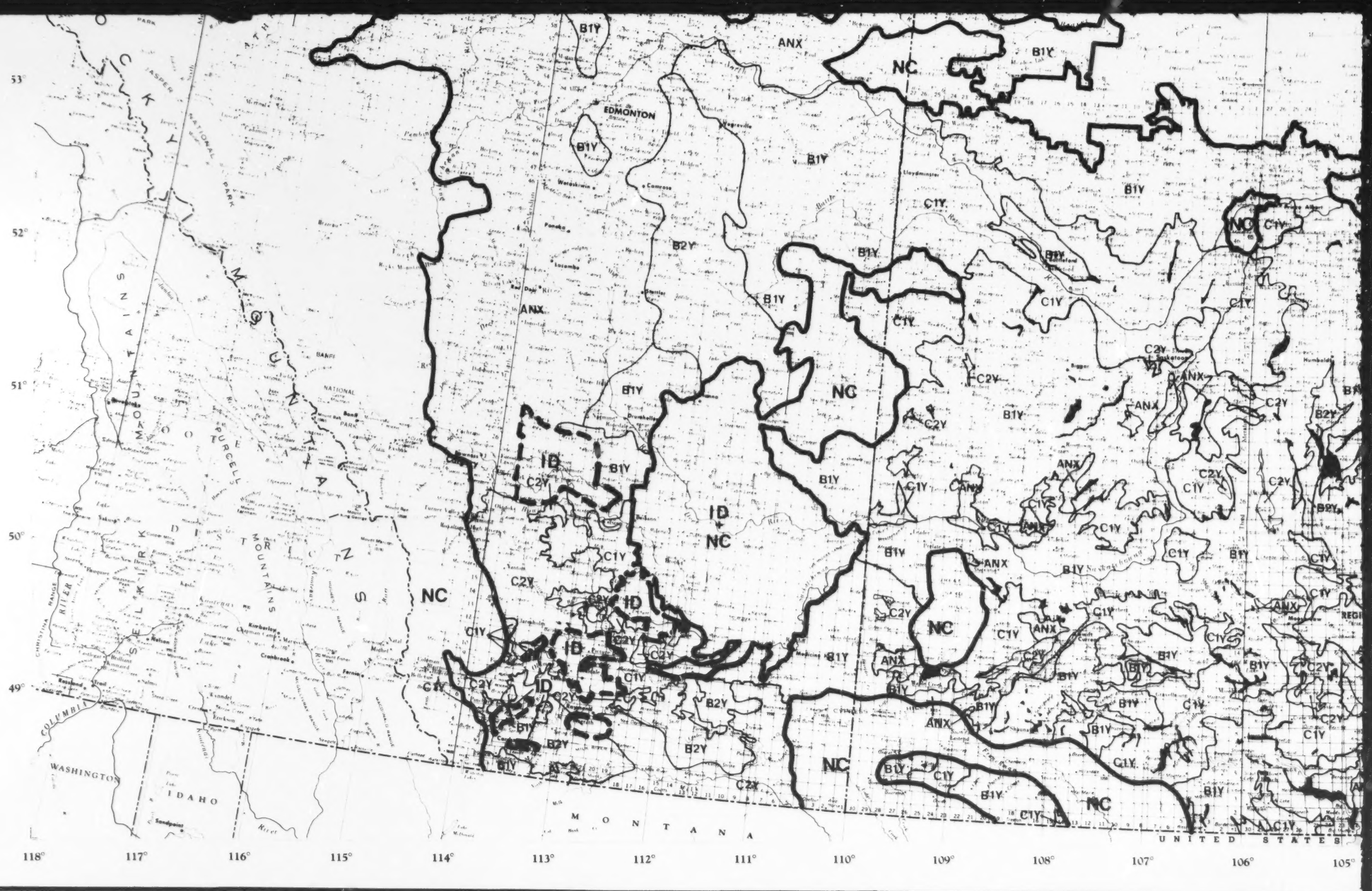
C1Y

B2Y

C2Y

B1W

ANX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52°
51°
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118°
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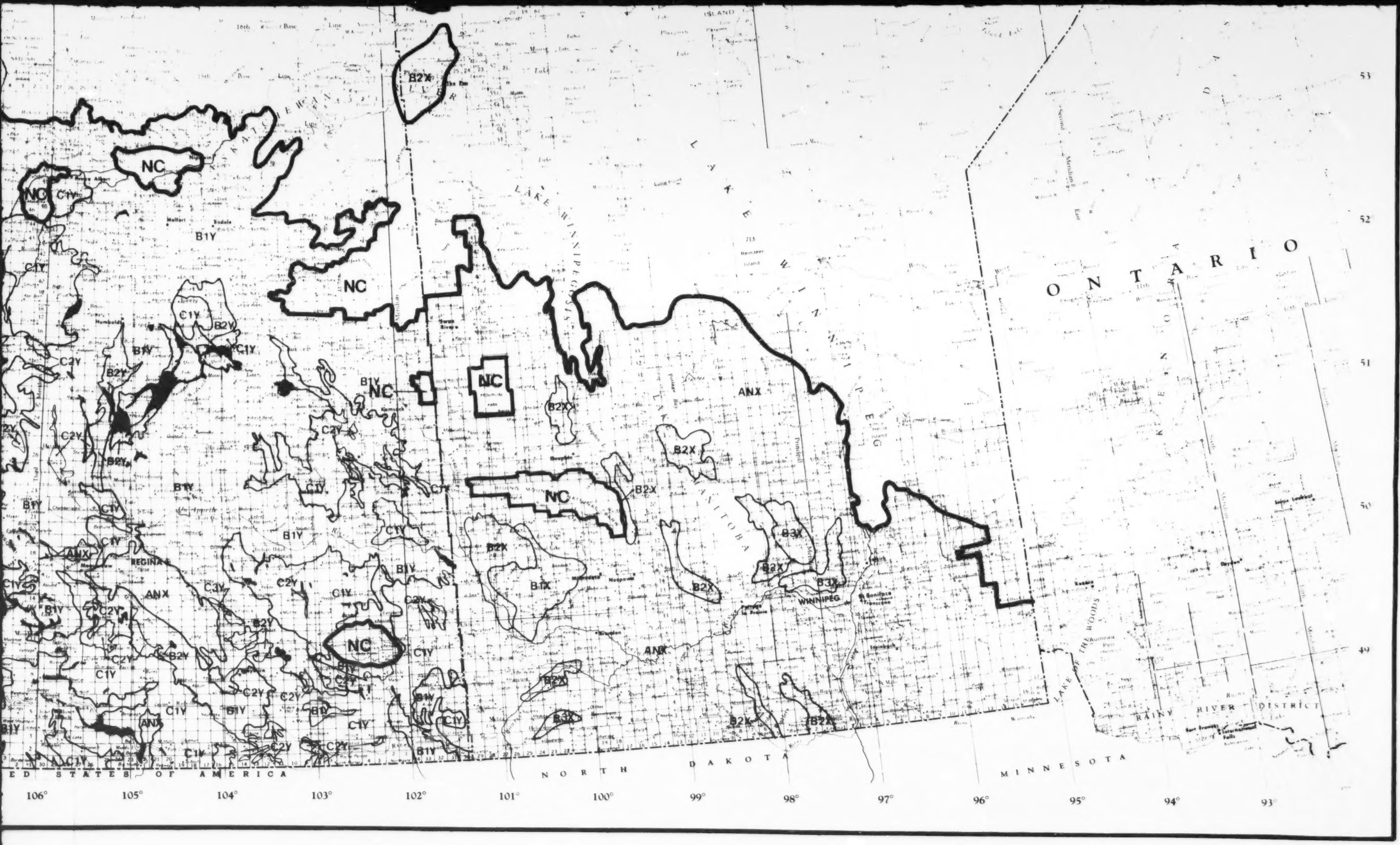
EDMONTON
BANFF
NATIONAL
PARK
JASPER
ROCKY MOUNTAINS
PURCELL MOUNTAINS
SELKIRK MOUNTAINS
COLUMBIA MOUNTAINS
DISTRICT
CHRISTINA RANGE
RIVER
COLUMBIA
WASHINGTON
IDAHO
MONTANA
UNITED STATES
B1Y
B2Y
C1Y
C2Y
ANX
NC
ID


NC
B2X
B1Y
C1Y
C2Y
B2Y
ANX
B3X
REGINA
WINNIPEG
ONTARIO
LAKE WINNIPEGOSIS
LAKE MANITOBA
LAKE OF THE WOODS
RAINY RIVER DISTRICT
NORTH DAKOTA
MINNESOTA
ED STATES OF AMERICA
106°
105°
104°
103°
102°
101°
100°
99°
98°
97°
96°
95°
94°
93°
53
52
51
50
49